# EDITORIAL.

## Root disease caused by Fomes Lignosus.

The two articles by Mr. R. P. N. Napper on the root disease caused by *Fomes lignosus* are of considerable importance, the first, because the views advanced are almost diametrically opposed to those held by previous investigators; the second, because the scheme for treatment has been proved to be a practical and successful method under estate conditions. The treatment has been in operation on a large scale on two estates in Malaya and results from both estates are reported to be extremely satisfactory.

It should be emphasised that the results published in the first article are the outcome of about 15 months' observations and it is obvious that such important findings must be fully substantiated by further work before they can be accepted. Up to date it has been generally assumed that the diseases caused by *Fomes lignosus* and *Ganoderma pseudoferreum* could be considered from entirely opposite points of view as regards treatment, the former being most serious in young plantations and not serious in older rubber, while the latter had not been found on young trees and did not become prominent before the trees were eight to ten years old. Recent findings indicate that this view will be reversed in the future and there is substantial evidence to show that the fungus *Ganoderma pseudoferreum* attacks rubber plants in the earliest stages and that it is not improbable to suspect that infection originally takes place through the cut-end of the stump which is inserted in the soil when planting with stumps is undertaken.

The work is of vital importance in any future planting policy which involves the consideration of the establishment of high- yielding bud-grafted areas, for combined treatment for both *F. lignosus* and *G. pseudoferreum* will become possible in the future, if the present indications are confirmed.

## Variations of Budding Technique.

Until recently there has been no important change in budding technique from that adopted when the method was first applied to the treatment of rubber tree seedlings.

The article by Mr. Sharp of the Botanical Division recording the results of various experiments carried out at the Institute Experiment Station indicates that, in budding of large stocks, by increasing slightly the period before opening a higher percentage of successes is obtained.

Fully matured (brown) budwood is also shown to give a higher proportion of successes than immature (green) budwood, although the latter can be used with quite satisfactory results, especially in the case of some clones.

### Tapping with Sunday Resting.

In the discussions on methods of reducing output or restriction of crop, to which so much attention has been paid during the last two years, the cessation of tapping on Sundays has been suggested. An enquiry was addressed to the Institute by Sir W. George Maxwell, K.B.E., C.M.G., asking for information as to the probable result. No information however was available and none was forthcoming as a result of a questionnaire addressed to District Planters' Associations in Malaya. Several estate Managers however agreed to carry out experiments on lines suggested and the paper published in this Journal contains the results of experiments on those estates which continued the experiment for a period of one year which was considered to be sufficiently long to obtain reliable records.

The results obtained show that the loss of crop is slightly less than the theoretical loss due to the reduction in the number of tapping days by cessation of tapping on Sundays.

This is in accordance with other modifications in tapping systems which involve rest periods.

### Forestry Methods of Rubber Cultivation.

Considerable interest has been aroused during the last year in the so-called forestry methods of cultivation of the rubber tree, as a result especially of lectures given in Malaya by Dr. H. N. Whitford of the Rubber Manufacturers' Association of New York in describing methods used by Mr. Birkemose on an estate in Pahang.

Previous observations published by the Soils Division of this Institute have indicated the importance of lowering the temperature of soils by shading, in order to reduce or prevent the rapid oxidation of the organic matter or humus in the surface layers and to maintain the conditions which exist in a well aerated soil under forest conditions in the tropics.

The general adoption of cover crops and the discarding of the previous policy of intensive clean weeding also indicate the attention which is being devoted to more scientific methods of soil treatment in relation to permanent crops such as the rubber tree.

As a result of the interest created in this important problem and the numerous enquiries received it was decided to draw up a memorandum on the subject embodying our views.

The article published in the Journal has been compiled by the Head of the Soils Division in consultation with the Heads of the Pathological and Botanical Divisions of the Institute, in order to include the various aspects of the problem.

It is shown that, while the method has many advantages in relation to soil conservation, our information on the pathological aspects especially in relation to root diseases of the rubber tree is at present meagre. Reference however to the article by Mr. Napper on "Root Disease of Rubber Trees caused by *Fomes lignosus*" indicates the significance of the procedure, in relation to the incidence of this disease in young rubber growing under such conditions.

It is however yet too early to form definite conclusions as to the effects at later stages of growth.

It must also be emphasized that this system of cultivation is not a "cure-all" for the ills of those rubber estates caused by a long history of previous cultivation under other crops or by prolonged neglect of soil conservation methods in the past.

In many cases, regeneration of such soils is not an economic proposition with the present stand of poor trees of which a large proportion possess inherent poor yielding qualities.

## Rubber Roadways Investigations.

The Annual Report of the Institute for 1931 published recently contains a summary of the progress of investigations carried out at the Institute from about March to the end of the year, particularly in relation to the possible utilisation of latex mixtures for this purpose.

It has also been considered desirable to publish a brief survey of investigations on this problem, including a description of the various rubber-capped blocks on which numerous trials are being carried out in Great Britain by Rubber Roadways Ltd. under the auspices of the Rubber Growers' Association.

The present lines of work are beginning to show promise although many difficulties have still to be overcome. It is also not possible to state at this stage whether any satisfactory rapid laboratory tests for ageing and abrasive qualities can be developed which will indicate the probable lasting qualities of any product prepared.

In any case actual service tests will probably have to be carried out before any product is used on a large scale, although suitable laboratory tests in relation to ageing and wearing qualities will be useful for differentiating between various products.

## Baling of Rubber.

The problem of packing of rubber otherwise than in wooden chests merits attention at the present time, when efforts for the reduction of costs are of considerable importance especially if it can be proved that other packing materials are equally suitable even if the rubber has to be stored.

The figures collected by Mr. Moore, in relation to packing in treated hessian or in "grass" matting indicate the economies which can be effected.

Efforts to bring about a change in this direction should be made by all producers, especially since it is also shown that British packing material can be used, whereas the present wooden cases are of foreign origin.

In addition, the possibility of treating the hessian with latex vulcanised by means of lime and sulphur is indicated. This would result in a useful consumption of latex.

# OBSERVATIONS ON THE ROOT DISEASE OF RUBBER TREES CAUSED BY FOMES LIGNOSUS.

BY

R. P. N. NAPPER.

## INTRODUCTION.

The fungus *Fomes lignosus* is associated with one of the two most destructive root diseases of the rubber tree in Malaya. This disease attacks rubber trees of all ages, but is most active during the first five years in the life of a plantation, when it often causes heavy loss of stand.

Careful inspection of infected trees, and of the soil surrounding them, shows that the disease is caused by a soil inhabiting, wood rotting fungus, which is able to migrate from one source of food supply to another by means of white rhizomorphic strands. These rhizomorphs have been freely accepted by all authorities as a vegetative phase in the life history of the fungus *Fomes lignosus,* because typical fruit bodies of this species appear so frequently upon the rotting remains of trees killed by the disease.

In spite of its economic importance, little attempt has been made in the past to place practical knowledge of the disease on a sound scientific basis. From practical field observations on its occurrence and control certain plausible deductions have been made concerning the life history of the causal organism and the mechanism of its appearance in plantations, but these deductions have never been seriously challenged from a theoretical point of view.

The investigation reported upon below has for its object a thorough examination of the whole problem by means of carefully controlled experiments. When the investigation is completed, it is hoped that the results will enable definite statements to be made with regard to the name and life history of the causal organism. With such information at hand, it should be possible to set about the task of framing effective schemes for the control of the disease with some hope of ultimate success.

The experiments were commenced in May 1931, and this present paper is a digest of a Progress Report dealing with the advances made from that time up to the end of January 1932.

Two main lines of investigation have been pursued, viz :—

(1) An investigation of the nature and mechanism of the disease.

(2) An investigation into the life history of the fungus *Fomes lignosus*.

The subject matter of the paper will be arranged under these two headings.

In order to avoid confusion, the same name has been used indiscriminately in referring to the different mycological units associated with the disease. There is strong evidence that this policy is justified, but it must be understood that no premature assertion is being made that the evidence is unquestionable.

## (1) Investigation of the Nature and Mechanism of the Disease.

### (A) Early History of the Disease and its Control.

*Fomes lignosus* as a parasite on the rubber tree has been known to the plantation rubber industry from very early days. It was first recorded on *Hevea brasiliensis* by Ridley (16) (as *F. semitostus*) at Singapore in 1904, and in the following year its occurrence was demonstrated on rubber plantations in Ceylon (11). Since that time it has been recorded as a parasite of importance in all the rubber producing countries of the eastern tropics. In Malaya its name is associated with the most destructive of the diseases to which young rubber trees are exposed in newly planted areas.

*The Name of the Causal Organism.* Great confusion exists in the literature of systematic mycology with regard to the name of the fungus which is known to the modern planter as *"Fomes lignosus"*.

Ridley (16), in his note on the first recorded appearance of the fungus on the rubber tree, directly connected the death of the trees he examined with the parasitic action of the fungus whose fructifications appeared on the moribund plants. These fructifications he assigned to the species *Fomes semitostus,* a fungus previously named and described by Berkeley from Indian collections. In giving the fungus this name Ridley was probably influenced by Massee (9), who, at Kew in 1898, thus named one of the specimens of a collection sent him by Ridley from Singapore.

In 1910-11 however, both Petch (14) and Lloyd, while studying type specimens of fungi at Kew Herbarium, arrived independently at the conclusion that the fungus causing a disease on the rubber tree was certainly not the fungus described by Berkeley as *F. semitostus*. Lloyd, in 1912 (7), was the first to write of the fungus under its familiar name of *F. lignosus,* and in 1915 (8) in his "Synopsis of the Genus Fomes", he published *F. lignosus* Klotzsch

as a valid species. Petch agreed, for in 1914 (12) he had referred to the fungus as *F. lignosus,* and in 1921 (13, page 261), in his classical treatise on rubber tree diseases, he authoritatively described it under its new name.

But the difficulties of nomenclature were not so easily overcome. In 1923 the whole vexed question was reopened by van Overeem (10), who declared that *F. lignosus* Klotzsch is only one form of a very variable fungus, of world wide distribution, which he referred to the new species *Rigidoporus microporus* (Swartz) van Overeem. This species, he claimed, included thirty four differently named fungi which were in his opinion synonymous, the most important from our point of view being *F. lignosus* Klotzsch and *Polyporous zonalis* Berkeley.

Petch (14) has recently made a further close study of the situation. He does not agree with van Overeem that *Fomes lignosus* and *Polyporous zonalis* are forms of one and the same species. Furthermore, he asserts that the fungus decribed by Lloyd (8) as *Fomes lignosus* cannot possibly be the fungus associated with the common root rot of rubber. Lloyd established the identity of his specimen of *F. lignosus* with *Polyporous microporus* (Swartz) Fries, a West Indian species, which Petch is convinced is not identical with the root disease fungus of rubber trees in the East. Petch concludes that the specimen examined by Lloyd was probably the true *Fomes lignosus* as originally described by Klotzsch, but that Klotzsch's type specimen came from the West Indies (there is other evidence for this) and not from Mauritius as was stated by Fries. If this is true, then the *"Fomes lignosus"* of the rubber planter is as yet an unnamed species.

The common name *F. lignosus* will, however, be retained for simplicity throughout this paper.

*Propagation of the Disease and Methods of Control.* Treatment for the control of the disease has been based in the past upon the measures employed in controlling other root rotting, rhizomorphous fungi. Parasites of this type are difficult to eradicate, since wind distribution of their spores is supplemented by vegetative distribution beneath, or along, the surface of the ground.

Theoretically it should be possible to eradicate such a fungus as *Fomes lignosus* if the following recommendations are rigidly followed :—Infected areas of a plantation should be isolated by deep trenches to prevent underground spread of the fungus. These areas should then be dug deeply, *all* infected material removed from the soil and destroyed, and the soil thoroughly sterilised. In order to prevent the subsequent reappearance of the disease all exposed rotting timber should be removed from both diseased and healthy areas; in this way the appearance of fructifications in the immediate

neighbourhood will be prevented, and even if the spores blow in from outside they will find but few situations in which to germinate and grow.

*Spread of the Disease by Wind-blown Spores.* There has always existed some doubt as to the practical advantages of the final paragraph of the above recommendation when dealing with the disease caused by *Fomes lignosus.* It has frequently been stated in Ceylon and Malaya that the fructifications of this fungus are permanently sterile, or at the most are only sparingly or infrequently fertile. If this were a fact, it would be an unnecessary refinement of control to attempt to prevent their appearance.

The following are some of the views which have been expressed on the subject :—

Gallagher (4), in 1909, admitted the probability of spore infection, but leaned towards the view that the appearance of the disease in a clearing is ".....due to jungle stumps affected previous to felling."

Bancroft (1), in 1912, considered that propagation by spores in a clearing ".....does not appear to count for much," but that the fungus spreads first from the stumps of jungle trees whose roots were infected before felling, and later from the roots of diseased rubber trees themselves.

Brooks (2), in 1916, remarked that during his short residence in Malaya he examined a large number of fructifications at different times of the year, and the majority of them were found to be sterile. He never succeeded in obtaining a spore deposit, and concluded that :—"In view of the apparent paucity of spore production it would be interesting to have fuller information concerning the manner in which the fungus first begins to spread in a young rubber plantation."

Petch (13, page 40), in 1921, states that ".....its occurrence on jungle stumps in new clearings can only be explained by spore infection, for it is quite contrary to all experience in field mycology to suppose that all such stumps were attacked by *Fomes lignosus* before the jungle was felled." In order to support his statement that the spores of the fungus are capable of creating new centres of infection, he gives two instances at least in which the appearance of the fungus could only be explained by the mechanism of wind-blown spores. He does not record spore measurements, however, and mentions that the fructifications when examined are often found to be sterile. He adds that this is probably because they have not been examined at the right season.

An official publication of the Department of Agriculture S.S. & F.M.S. (6), issued in 1921, states quite definitely that.—"The

fruit-bodies of this fungus are remarkable in that they are persistently sterile."

Bryce (3), in 1922, assigned the method of propagation in a new clearing to infection of stumps by wind blown spores, and to subsequent underground spread of the fungus from these stumps as they rot.

The fertility of the fructifications does not seem to have been called into question in the Netherlands East Indies. Steinmann (21), in his book on the diseases of the rubber tree published in 1925, makes no particular reference to the matter beyond the simple observation that young sporophores are abundantly fertile ("De sporen.....bij jonge vruchtlichamen altijd in groot aantal voorhanden.").

A final turn has been given to this controversy during the course of this present investigation. It has been discovered that, in Malaya, fructifications bearing large numbers of viable spores are produced in abundance under certain climatic conditions, which probably occur at least once a year and last for a considerable period. In this country, therefore, wind dispersal of infection is highly probable, and the degree to which this method of propagation influences the spread of the disease is being made the subject of careful research.

*Spread of Infection through the Soil: Practical Control Measures.* The ideal recommendations for the control of the underground spread of *Fomes lignosus* (as outlined in a previous paragraph) are quite unsuitable for practical application in young clearings. If faithfully carried out, they would require thorough sieving and careful hand picking of the soil to a depth of not less than three feet. This would cost at least $300 per acre, besides resulting in a temporary loss of fertility to the soil, and it is doubtful whether such an expenditure could in any instance be justified by the subsequent elimination of loss by root disease.

The foregoing remarks apply, of course, to control measures carried out when the disease is at its height, i.e. from two to five years after the clearing of the jungle. At this stage the soil is still full of rotting timber. In later years, when most of the jungle timber has rotted away, and during the preparation of replanted areas in which only the relatively small and shallow rooted rubber tree has to be dealt with, the ideal recommendations can be applied in practice. They should be followed with care when any previously diseased areas among mature rubber are being cleared for replanting.

To turn again to the consideration of the treatment of the disease in young clearings, it has always been the aim of those interested in the problem to devise a scheme of control of moderate cost, the results of which would amply justify the necessary expenditure. In formulat-

ing such schemes, the main idea worked upon has been that *the incidence of root disease in a planted area varies directly with the total amount of timber left in and upon the soil at the time of planting, and consequently, that the greater the amount of timber removed from the area at that time, the lower will be the incidence of root disease on the future stand of trees.*

This idea first saw the light in the old recommendations for the stumping of plantations employed both as a preventive and a curative measure for the control of *Fomes lignosus,* and reached its logical conclusion in the policy of *"clean-clearing"* about which so much has been said and written during the past decade.

*Clean-Clearing.* In pursuing a policy of clean-clearing while bringing a newly felled jungle area into cultivation, all the debris left on the surface of the soil, after the burn, is removed before planting is commenced; charred logs and stumps and many of the larger surface roots are eliminated, and only those portions of the root systems of the jungle trees are left to rot in the soil which cannot be dragged out conveniently along with the stumps.

Up to this point the policy of clean-clearing follows closely the ideal recommendations for the complete eradication of root disease. But clean-clearing stops here, since the remainder of the timber is buried in the soil, and can only be reached by the costly operation of systematic deep digging. In carrying the ideal recommendations to their conclusion, the total expense involved is quite three times the cost of the preliminary clearing, two thirds of the expenditure being absorbed in removing the timber buried in the soil, i.e. in removing the last 10 or 15 per cent. of the timber left on the area after the burn.

According to the old idea that the incidence of root disease varies directly with the amount of rotting timber in the soil, the very expensive removal of this small amount of residual timber was looked upon as a needless refinement of control. Clean-clearing, it was claimed, at a fraction of the cost, would provide as close an approximation to complete control of *Fomes lignosus* as was practically desirable, and further, would control other root affections, mycological and entomological, to a similar extent.

In the boom period which followed the War when much new planting was carried out, the policy of clean-clearing gained favour in this country. In addition to the reputed advantages from the point of view of root disease control it has several other features which make a special appeal to the planter. It facilitates supervision and speeds up the activities of the tapping and weeding gangs. These advantages outweighed the disadvantages of high initial cost, danger of soil erosion, and (a less obvious disadvantage but one which has since been shown to be highly important) the danger of impoverish-

ment of the soil, and it is not surprising that in 1920, when a prize was offered by the Incorporated Society of Planters for the best essay on the subject "Is clean-clearing commercially sound?", the two successful entrants should both have declared wholeheartedly in favour of the policy (22, 20).

From that period, until the activities of this Institute commenced, clean-clearing was adopted as a normal planting policy on numerous estates, but no precise investigation was made to test the validity of the claims upon which its popularity rested. The need for such investigation was immediately obvious to Dr. J. R. Weir when he arrived in Malaya to take over the position of Head of the Pathological Division of the Institute. As soon as the Experiment Station was opened up at Sungei Buloh he initiated a number of experiments for the direct comparison of the incidence of root disease under clean-cleared and uncleared conditions ; these experiments are now beginning to yield results.

### (B) Recent History : Experiments carried out at the Experiment Station, Sungei Buloh.

The experiments had been in hand for two and a half years before they came under the direction of the writer. Complete records of the progress of root disease due to *Fomes lignosus* have been difficult to assemble, but it was decided to analyse the available records so that a guide might be provided to the lay-out of future experiments.

*Definitions.* In order to deal with these records it was necessary, in the first place, to excogitate certain terms in which to describe the properties of an attack of *Fomes lignosus* on a particular area at a particular time, and to discover suitable numerical expressions, determinable directly from the disease records, by which these terms should be defined.

It has been decided to employ the following terms and definitions :—

$$F = \textit{Fomes Incidence} \text{ at a given time (per cent.)}$$

$$= 100 \times \frac{\text{Number of trees in the area diseased at that time}}{\text{Total original stand}}$$

$$M = \textit{Fomes Mortality} \text{ at a given time (per cent.)}$$

$$= 100 \times \frac{\text{Number of tree deaths since planting}}{\text{Total original stand}}$$

$$A = \textit{Intensity of Attack} \text{ up to a given time (per cent.)}$$

$$= 100 \times \frac{\text{Total number of planting holes in which the fungus had developed since planting}}{\text{Total original stand}}$$

F is intended to indicate the magnitude of the disease at the moment under consideration;

M is intended to indicate the extent of the ravages of the disease in the past, and hence to suggest, in conjunction with F, whether the disease was, at the moment under consideration, increasing or decreasing in intensity;

A is intended to represent the potentiality for development of the fungus under the conditions obtaining in the area. This term has been employed principally in comparing potentialities in different areas under different methods of planting practice.

*Experiment I.* A level block, 10 acres in extent, was felled and burned and divided by lines running north and south into three areas, viz :—

(a) A two acre plot in which the timber was piled after burning.
(b) A four acre plot which was clean-cleared after burning.
(c) A four acre plot which was left untouched.

Plot (a) is still unplanted; plots (b) and (c) were planted in January 1929, the planting distance being 22 ft. × 22 ft.

The experiment was left untouched until September 1931, and it is considered that the data which had been collected up to that time, with regard to the incidence of root disease due to *Fomes lignosus* in plots (b) and (c), may be regarded as significant in demonstrating the difference between the incidence of this fungus on clean-cleared and uncleared areas.

The records of the occurrence of *Fomes lignosus* in the plots previous to May 1931 were supplemented by two thorough root examinations in the months of May and September of that year. After the second examination, all the available records were analysed to determine the number of planting holes in which the fungus had developed at some stage during the progress of the experiment.

It was discovered that, in the clean-cleared area, 106 planting holes had at some time been infected, while in the uncleared area the figure was only 67. Using percentage "A" to indicate the potentiality for development of the fungus under the existing conditions, then :—

| | | |
|---|---|---|
| In the clean-cleared area | A = | 29.4 per cent. |
| In the uncleared area | A = | 18.6 per cent. |

It appears probable from a consideration of these results, that the incidence of attack in the two plots demonstrates a significant difference between the potentialities for development of *Fomes lignosus* under clean-cleared and uncleared conditions of planting, and that, up to the age of three years, the balance is greatly in favour of the latter.

*Experiment II.* The results of this experiment provide further information on the effect of clearing methods on the subsequent

incidence of *Fomes lignosus,* and information also on the effect of the establishment of cover crops on the incidence of the disease.

Two similar adjacent jungle blocks were felled and burned, each being 10 acres in extent, and having a common boundary running from north to south. The eastern block was clean-cleared before planting, the western block retained all its surface timber and stumps. Strips of three different cover crops were established, running across the double block from east to west, the strips of cover being separated by control strips of equal width bearing no cover.

Records of previous root disease control work in these blocks are available, and were supplemented, as in Experiment I, by two careful root inspections before the figures were compiled for analysis. On analysis the records showed that in the clean-cleared block 189 planting holes had been infected since planting, as against 82 holes in the uncleared block, i.e. :—

| | | | |
|---|---|---|---|
| In the clean-cleared block | A | = | 20.3 per cent. |
| In the uncleared block | A | = | 9.2 per cent. |

This difference between the values of "A" in clean-cleared and uncleared areas is even more striking than the difference obtained in Experiment I.

In order to investigate the effect of cover crops on the development of the disease the percentage "A" was worked out for the various strips of cover and control (boundary rows being excluded). The following values were obtained, working from south to north through the blocks :—

| | | | |
|---|---|---|---|
| In 1st control strip | A | = | 23.4 per cent. |
| In strip under *Leucaena glauca* | A | = | 18.4 „ „ |
| In 2nd control strip | A | = | 20.9 „ „ |
| In strip under *Crotalaria anagyroides* | A | = | 5.7 „ „ |
| In 3rd control strip | A | = | 16.0 „ „ |
| In strip under *Calapogonium mucunoides* | A | = | 6.1 „ „ |

Average values :—

| | | | |
|---|---|---|---|
| In area without cover | A | = | 20.1 „ „ |
| In area with cover | A | = | 10.1 „ „ |

It would be unjustifiable to make categorical statements with regard to the effect of cover crops on the incidence of root disease from a consideration of this one experiment alone, but it may be inferred that the incidence of *Fomes lignosus* tends to be less in areas carrying cover crops than in areas without cover.

This conclusion is of great interest as it appears to apply generally to the three different cover crops employed, viz. *Leucaena glauca* (Lamtoro), *Crotalaria anagyroides,* and *Calapogonium mucunoides,* the first two of which are of a bushy and the last of a creeping habit. Further experiment along these lines is obviously necessary.

*Experiment III.* In a 10 acre planted area, adjoining the highly infected block on which Experiment I is being carried out, secondary jungle (belukar) has been allowed to grow up among the rubber trees. No weeding has been done subsequent to planting, and the belukar has only been pruned when it has overtopped the rubber.

Records of the occurrence of root disease in this area show that the incidence of *Fomes lignosus* has been of negligible proportions. In September 1931, when the rubber was three years old, a root examination showed that.

*Fomes Incidence* in the area = F = 1.7 per cent.
and *Fomes Mortality* = M = 1.7. „ „

These figures are much smaller than those for any other field of the same age on the Experiment Station.

*Discussion.* The results yielded up to the present by these experiments are remarkable in that they are entirely at variance with the ideas which held sway when the experiments were initiated.

At that time the incidence of root disease in a clearing was presumed to vary consistently with the amount of rotting timber in the soil, the incidence being zero in areas carrying no timber at the time of planting, and becoming increasingly severe in areas less and less properly cleared. The results of Experiment I, II and III indicate that these ideas are no longer tenable, and suggest a very different picture of the manner in which the incidence of root disease varies with the amount of timber left in the soil at the time of planting.

The numerical analysis of the results has been supplemented by an exhaustive graphical analysis which cannot however, for lack of space, be dealt with here. The results of this graphical analysis support in detail the deductions which have been made from the figures given above; these deductions are further supported by considerable masses of unconnected data obtained in the course of normal pests and disease work on other fields at the Experiment Station. Nevertheless, further experimental work is necessary before the deductions can be accepted without reserve.

The results of experiments I, II and III suggest that the curve obtained by plotting the incidence of *Fomes lignosus* in a young clearing, against the amount of timber left in the soil by the clearing methods employed, would probably be of the type shown in Fig. I. As the amount of timber left in the soil increases from zero, the subsequent incidence of attack among the young plants rises sharply from zero to a maximum and then falls gradually away until, in the extreme instance where belukar is allowed to develop among the rubber trees, the incidence of the disease upon the latter is very small.

A reasonable explanation can be given for the apparently anomalous results of the above experiments if the following three postulates are made :—

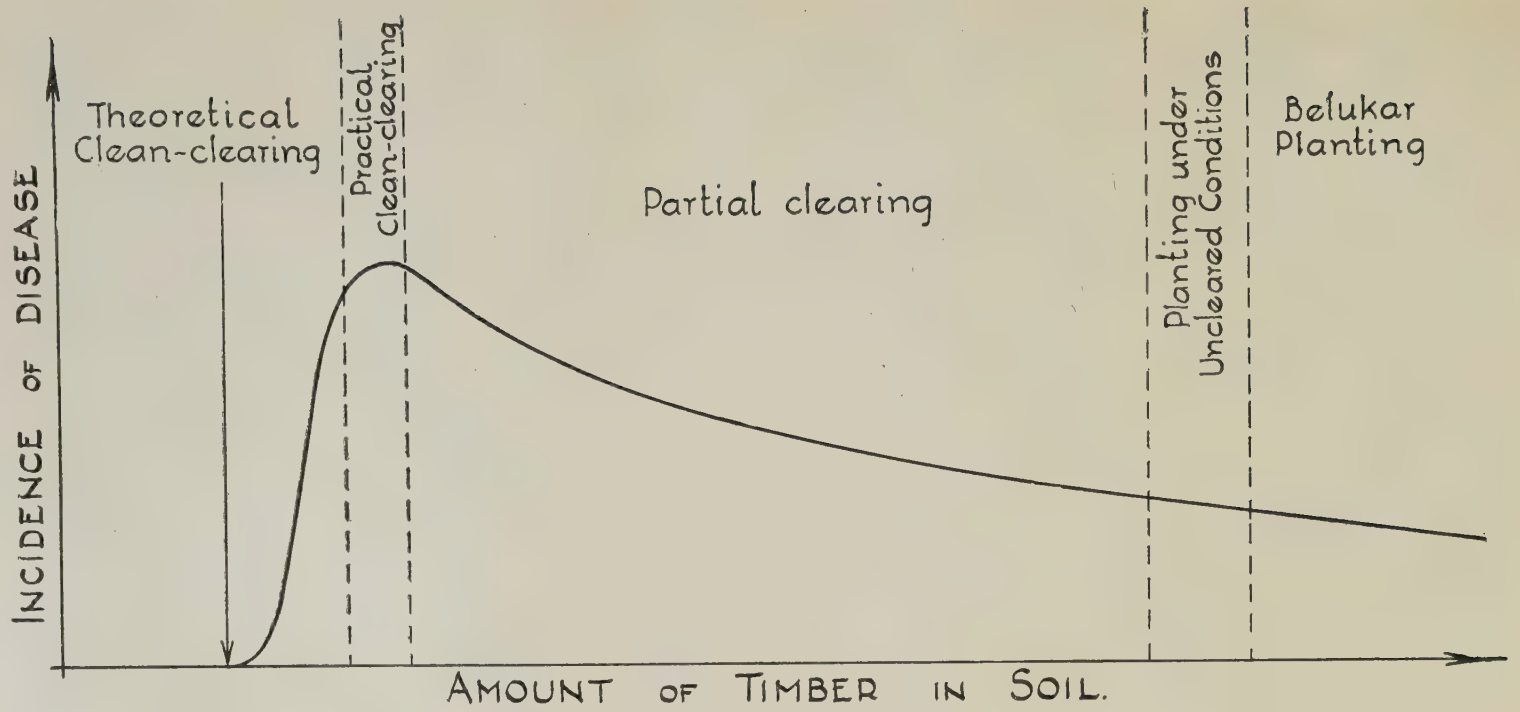


FIG. 1.

Diagrammatic representation of the probable relation between incidence of disease and the amount of timber present in the soil under different systems of planting.

(1) That the presence of infection in the soil of a clearing is due chiefly to the presence of the disease in the jungle stand before felling. *This is very probably true.*

(2) That the distribution of the disease in the future stand of rubber is governed by the original distribution in the jungle. *This follows from (1) if (1) is correct.*

(3) That the fungus does not begin to form rhizomorphs until the food material in the substratum upon which it is growing begins to be exhausted. *This postulate is supported by general mycological considerations and by the experience of observation.*

If these postulates are accepted the following deductions may be made :—

(a) If all the timber is removed from the soil before planting then all danger of infection in the clearing will be eliminated.

(b) If a small amount of generally distributed material is left in the soil the distribution of infection will be the same as if no material had been removed, the amount of food material available for the fungus will be small and soon exhausted and there will be an early formation of rhizomorphs, and these rhizomorphs will wander through the soil until the source from which they originated is exhausted or until they have encountered the roots of a rubber tree, there being no other material in the soil to intercept their progress. Under these conditions of planting the chances of attack upon the young trees will be high.

(c) If an increasing amount of timber is left in the soil at the time of planting there will be a double effect. Firstly, the food material available for the fungus will increase and the formation of rhizomorphs will be delayed, and secondly, when the rhizomorphs are formed, there will be an increasing amount of timber in the soil other than rubber roots upon which they can fasten and feed. Under these conditions of planting chances of an attack by *Fomes lignosus* on the stand of young rubber will be increasingly diminished.

(d) If secondary jungle is allowed to regenerate in a young clearing, the proportion of soil-borne timber belonging to the crop plant will be very small compared with the total amount of material which can be parasitised or saprophytised by the fungus. Under these conditions the probability of attack upon the crop plant will be very small indeed.

If the above reasoning is sound then there is no difficulty in explaining why the presence of a cover crop, even of a woody plant such as Crotalaria, which is known to be parasitised by the fungus, tends to reduce the incidence of *Fomes lignosus* upon the rubber trees among which it is planted. The cover crop presents an enormous amount of food material on which the fungus can feed both as a parasite and as a saprophyte, and thus reduces the chance of attack upon the crop plant. There is probably very much more

mycelium in the soil under a heavy cover crop than under clean weeded conditions, but this is discounted as indicating the probability of a higher incidence of attack upon the rubber trees interplanted with a cover because of the larger amount of material in the soil other than the roots of rubber trees upon which the mycelium can feed.

Up to the present time controlled experimental observations on root disease due to *Fomes lignosus* have not gone beyond the third year, and the results of extended experiments may necessitate a complete rearrangement of these ideas. After reading the above discussion, even if the arguments are accepted, the question will be asked, how will the shape of the curve in Fig. 1 alter as the age of a plantation increases? Although methods of planting under uncleared conditions, or conditions of secondary jungle, may greatly reduce the loss of stand through root disease during the early years of the clearing, the effect may be one of delayed action only. It has been deduced above that the probability of attack upon the crop plant is greatest when other rottable material in the soil is nearly exhausted, and it may be that, in an estate which was planted under uncleared conditions, or under conditions of secondary jungle, the disease will attack the crop plant in an epidemic fashion in later years when the jungle timber in the soil becomes exhausted, or when the belukar (or other cover crop) is shaded out by the rubber.

There is very little evidence at hand on which to base an answer to the question raised in the previous paragraph, and it is even impossible to say, until the results of controlled experiments are available, in which direction the reply will tend. There are one or two considerations which may be cited as guides, but their importance cannot yet be correctly assessed.

Evidence suggests that as the rubber tree grows older it becomes more resistant to the attacks of *Fomes lignosus* on its roots, and further, that the culture of *Fomes lignosus* in the soil of a new clearing stales after a time and is not subsequently so active as during the first few years after clearing. This evidence is based on the observation frequently made that the incidence of the disease in a new clearing tends to rise to a maximum during the period between the second and the fourth years after burning off, and then to drop to a comparatively low figure.

One very good illustration of this tendency is presented by the disease records of two adjacent estates in North Perak, totalling together about 1,000 acres, over half of which no control work was done while over the other half control measures were carried out along orthodox lines of isolation and deep digging. In each half the loss due to the disease was high (although well within the limits allowed for by the density of planting) but showed a period of maximum rate of mortality within the age limits given above. The whole

area is now six to eight years old, and the rate of mortality has fallen to a low figure in both the treated and untreated areas.

There is a distinct possibility that the operation usually referred to as the "cleaning up of old Fomes patches" in areas such as these where the fungus has naturally staled will be attended by considerable risk. A staled culture is not necessarily dead, and if disturbed may be given a new lease of life. This type of rejuvenation may account for the rapid growth of mycelium which sometimes occurs in replanted areas. A certain well-known planter reports that in experimental replanted areas on his estate, which have been very carefully dug over and hand picked, many vigorous reinfections have developed. In several instances the soil around the infected plants was found to be bound together by masses of mycelium, but careful search did not reveal the source of reinfection.

The staling of soil cultures of *Fomes lignosus* has been observed to take place after two or three months in root disease investigation boxes, and the occurrence of a similar phenomenon in the field is not impossible. Whether it is due to the presence of toxic bodies in the soil actually engendered by the growth of the fungus itself, or to the development and activity of other competitive organisms is not known. It is probable that under jungle conditions the fungus is kept entirely in check by these phenomena, but that the early upheaval occasioned by felling and burning in some way favours the rapid development of *Fomes lignosus* above any of its competitors. This may account for the fact that the fungus has an early period of great activity, rising to a maximum soon after planting, and falling off gradually as the conditions in the soil become more normal.

According to this argument the presence or absence of rubber trees in a clearing does not affect the rise and fall in the activity of the fungus ; the peak of the attack is governed by the time of clearing and burning and not by the time of planting. It is not usual for an interval of several years to intervene between burning off and planting, and information on this point is difficult to obtain. Useful evidence will be provided when certain particular areas on the Experiment Station, on which planting has been delayed, are brought into cultivation.

It may be of some significance that the attack of *Fomes lignosus* developed in Block 5 contemporaneously with the attacks in Blocks 2 and 4. These three blocks were burned off at the same time, but Block 5 was allowed to lie fallow for a year before planting.

### (C) Treatment of the Disease.

#### (a) Preventive Treatment.

Before it is possible to frame recommendations for preventive measures the following question must be answered: *What is the*

*principal source of infection from which the disease so commonly found in a young clearing develops* ?

There are two possible solutions to this problem :—

(1) *That the disease develops in, and spreads from, the root systems of jungle stumps infected by wind-blown spores after felling.*

(2) *That the disease develops principally from vegetative sources, present in the jungle soil before clearing, which have received considerable stimulus to growth by the process of clearing and burning.*

Until a short time ago, when the fertility of the fruit bodies of *Fomes lignosus* was frankly doubted, solution (1) would have been disregarded, but the results of the present investigation have bestowed upon it a new significance. Following the suggestion of Petch that the fruit bodies produce spores only under certain seasonal conditions, sporophores were examined at various periods during the year. As is described in Section (2) of this report, there was a profuse development of fructifications on all sorts of substrata after the heavy rains in the early part of December 1931, and every fruit body examined at that time was found to be sporing freely. Sporing has continued up to the present time, but the fructifications have now lost their freshness and spores are much less abundant.

The spores germinate very readily in water and on nutrient agar, and there is no longer any doubt that at certain periods of the year (probably after any period of prolonged wet weather) spores of the fungus, capable of germination under suitable conditions, are shed in great numbers from the sporophores and are distributed widely by the wind.

Experiments are necessary, and will be carried out at a favourable opportunity, to determine the ability of spores to resist exposure to normal atmospheric conditions in the field. Such experiments will indicate the degree to which the spread of infection is influenced by wind dispersal of spores. Until experiments of this type have yielded results there is only indirect evidence on which an estimate of this degree can be based, and this evidence is often contradictory.

In Experiments I, II and III the incidence of the disease has been significantly lower on areas bearing all the original stumps, which have therefore been exposed to the maximum amount of spore infection, than on areas from which the timber was removed immediately after burning, in which the possibility of spore infection has been greatly reduced. But against this there is the evidence of Block 5, which was allowed to lie fallow in a partially cleared condition for a year after burning, and was then clean-cleared. This block (a clone trial block) has been far more heavily attacked than

any other block on the Experiment Station ; it has already lost 13 per cent. of its stand through root disease, and the disease is still in an active condition. This may indicate that there was widespread infection of the stumps by spores while the block was lying fallow.

The analysis of the root disease records from Block 5 has raised several other interesting points. Conditions have certainly conspired within the block to bring about a significantly higher percentage attack than has occurred in any other block on the Experiment Station, but there are so many interacting factors, each of which might account for the abnormal intensity, that no single factor can be chosen as being the most important. It has recently been discovered that the position was still further complicated at the time of planting because the stumps with which the block was planted were obtained from nurseries heavily infected in parts with *Fomes lignosus*. Records of planting are still in existence, and will be studied carefully to see whether the infection might not have been carried to the field on the planting material.

It will be of considerable importance to discover if possible the reason for the heavy attack in Block 5. This is an example of a field of valuable material in which every effort was made to protect the plants from infection, and it may be that some of the precautionary measures employed actually aggravated the attack instead of mitigating it. The abnormally high incidence of disease in the block may be due either to (a) a high incidence in the original jungle stand, (b) to infection brought to the field on the planting material, (c) to the infection by spores of the exposed jungle stumps while the field was lying fallow, or (d) to the effect of clean-clearing.

To return again to the question of preventive treatment, solution (2) of the problem enunciated at the begining of this subsection will be considered of greater importance than solution (1) until evidence is forthcoming to show that the spores are able to withstand considerable desiccation. With this decision in mind, and remembering the results of experiments already described, it has been concluded that the least expensive and most successful methods of planting in order to avoid serious loss of young trees by root disease are, in order of merit :—

(i) Planting under uncleared conditions and allowing a natural cover of secondary jungle to regenerate.

(ii) Planting under uncleared conditions with the establishment of an artificial cover crop.

(iii) Planting under uncleared conditions with subsequent clean-weeding.

To these may be added :—

(iv) Planting under conditions of absolute clean-clearing, i.e.

after all timber, both above and below the surface of the soil, has been eradicated.

Methods i, ii and iii have considerable agricultural advantages over the practice of normal clean-clearing with clean-weeding which was, until recently, the ideal aimed at by most planters. In the first place, belukar, or lying timber bound by a cover crop, or even lying timber alone, serves to prevent soil wash to a greater or less extent. In the second place, a thick covering over the surface soil prevents the development of excessively high temperatures.

It has been pointed out by Sanderson and Haines (18) that high temperatures in the surface soil lead to a rapid release of available food material through enhanced micro-biological activity, and that this probably accounts for the fact that the growth of seedlings in clean areas is at first more rapid than in covered areas. Destruction of organic material is so rapid under conditions of tropical sun and rainfall that after a few years exposed soil becomes sterilised, the rapid growth of the young plants is retarded, and the initial advantage lost. When the soil is shaded however, the destruction of buried organic matter is less rapid, and the loss is continually made good by contributions from external sources. Early growth of seedlings under such conditions is not so rapid as in clean areas, but it is constant, and can be maintained at its original level for an indefinite period.

After a time therefore, trees under covered conditions will reach the same growth level as that attained in clean areas of the same age, and it is probable that in later years the advantage of growth will be in favour of the former. This levelling up process has been recorded by Haines (5) as beginning as early as the end of the third year after planting. His observations were based on the records made by the Soils Division of growth in the blocks in Experiments I, 11 and III.

Planting method (iv) is far too expensive for use on a field scale, but it is appended to the above list because of its claim to be infallible, but for the danger of spore infection from outside, in preventing the development of root diseases caused by fungi such as *Fomes lignosus*. An investigation of the method, with a view to determining its cost and its feasibility for commercial application, was initiated at the Experiment Station by Mr. A. R. Sanderson while acting as Head of the Pathological Division.

*Experiment IV.* A clean-cleared area of about 3 acres in extent was dug over to a depth of 3 feet, and every particle of woody material large enough to be handled was removed. It was realised that even a small amount of timber carelessly passed over might vitiate the whole experiment and, in order to avoid the risk, the soil, as it was dug, was passed through screen sieves under constant supervision.

The cost of the operation worked out at $450 per acre exclusive of the cost of the original clean-clearing, in spite of the fact that the soil is light and easily worked. Loss of fertility was severe ; the humus was destroyed so rapidly that the soil looked like sand, and the area was familiarly referred to as the "tin mine". When digging was completed the area was planted with rubber and a cover crop, but several successive replantings of both were necessary before either became established. As soon as a continuous cover was obtained over the area the stunted rubber seedlings began to develop normally, but about a year's loss of growth was incurred.

The area has been kept carefully isolated from the surrounding untreated soil, and it is large enough to warrant a comparison being made in later years between the incidence of root disease within its confines and the average incidence over the whole block in which it stands. If cases of attack by *Fomes Lignosus* do occur in this area there is a very high probability that they will have been brought about by spore infection from without.

*Replanted Areas.* So little new planting is being carried out in these days of financial stress that recommendations dealing with the best methods of clearing jungle timber for the prevention of root disease in young rubber are not of any great importance at the moment. A considerable amount of replanting is being done, however, for the replacement of old unremunerative stands of seedling rubber by high yielding budgrafted material is becoming imperative on many estates. Questions dealing with the eradication of *Fomes lignosus* in these old areas before replanting are being raised more and more frequently.

There has been little opportunity of investigating the problem during the past year, but from general considerations it seems advisable that all trees in replanted areas should be examined for signs of *Fomes lignosus* before they are felled, and particular care paid to the removal of infected trees during the clearing of the old stand. Well defined Fomes patches should be dug over to such a depth that all buried timber can be removed from the soil and destroyed, and the soil should be thoroughly exposed to the sun.

These control measures are of the same type as those recommended by Sharples and Sanderson (19) for the eradication of *Ganoderma pseudoferreum* from old rubber areas before replanting, and the treatment of the soil for the elimination of both diseases may run concurrently. It must however be borne in mind that while complete removal of diseased material from the soil will completely eradicate Ganoderma, which cannot as far as is known exist in the soil apart from its source of nourishment, yet *Fomes lignosus is* able to exist independent of its food supply and the removal of timber from an area infected with the latter fungus *must* be supplemented

by careful digging and exposure of the soil to the sterilising action of the sun.

It is quite possible that the cultivation of old Fomes areas will lead to a rejuvenation of the fungus lying dormant within them, and that prophylactic measures carelessly carried out will lead to a much more extensive attack among the young trees than would have occurred had no deep digging been attempted. *Adequate and trained supervision is essential if the success of preventive measures is to to be assured.*

### Curative Treatment.

Advisory work in connection with the control of *Fomes lignosus* is chiefly concerned with curative measures suitable for application in heavily infected areas of two to four-year-old rubber.

After some experience in framing schemes of control on various estates under various conditions of cultivation in different parts of the country, the conclusion has been reached that it is well nigh impossible to reduce recommendations to a common formula applicable to all problems ; each separate case must be treated on its merits.

There are two main lines of argument upon which recommendations may be based :—

(1) *If the diseased areas are dug deeply and all timber removed from the soil, and the soil is thoroughly exposed to the sterilising action of the sun, then the disease will be eradicated once for all from the areas.*

(2) *If all trees are regularly inspected and suitably treated so that the fungus is unable to become established in their root systems during the first four or five years of their life, then the fungus will be gradually exhausted from the soil, and subsequently the trees, being more vigorous, may be left to fend for themselves.*

A scheme of control based upon argument (1) becomes, in effect, an example of absolute clean-clearing deferred for a few years after planting. It is theoretically sound as far as the life history of the fungus is known, but it has the practical drawbacks that its expense is often prohibitive, and that, in some instances, its employment may lead to a serious loss of soil fertility. Further, if it is demonstrated, as is quite possible, that the spores of the fungus can remain viable after considerable periods of exposure to atmospheric conditions in the field, then one of the main supports of the argument, viz., that the scheme will ensure permanent eradication of the disease, will be seriously weakened. The cost of such a scheme of control will be less than that of absolute clean-clearing since considerable rotting of timber usually takes place before the disease develops extensively in a young plantation.

Control measures based on argument (2) have not yet passed beyond the experimental stage. The argument is founded upon the fact that, at the inception of an attack, the mycelium of the fungus remains more or less epiphytically upon the outer surface of the bark for a considerable time before penetrating beyond the inner layers of the cortex. While in this epiphytic condition the mycelium can be destroyed by the application of a fungicide, and it should be possible, therefore, by periodic root treatments alone, at suitable intervals, to prevent to a large extent the establishment of fresh attacks in an infected area. By this means adequate control of the disease should be obtained without the necessity of doing any more digging than is necessary to expose the root systems of the rubber trees for inspection.

The idea of curing infected trees by root treatment with a fungicide is by no means new, but there is a paucity of published information on the subject. As early as 1914, Richards (15), in Malaya, reported that considerable success had been obtained on some estates by scraping away mycelium and diseased wood from the roots of infected trees and applying Bordeaux Mixture in the form of a thin paste. It the same year, at the International Rubber Congress at Batavia, Rutgers and Arens (17) reported a similar method from Sumatra in which Carbolineum was the fungicide employed.

From that time onwards little organised work on the problem was carried out in Malaya until this Institute came into being, but as soon as the disease began to make its appearance at the Experiment Station a detailed investigation of the problem was undertaken by the Pathological Division. The investigation was initiated by Mr. A. R. Sanderson, who tested the efficiency of copper sulphate, lime, Uspulun, and many polysulphide mixtures (experimental and proprietary) as fungicides for the control of *Fomes lignosus*. Unfortunately the experiments were not completed and are unpublished, but the disease records kept, and the methods of treatment evolved during the course of the experiments, have been of great assistance in the compilation of this paper.

During the present investigation it has been decided to reduce the number of fungicides under observation, and to try them out on a large scale over an extended period of time. Copper sulphate promised to be the cheapest and most efficient for the purpose in view, and was chosen to be tested first.

*Scheme of Control on the Experiment Station.* The scheme of control which was devised for the test is dealt with in detail in the short article, entitled "A Scheme of Treatment for the Control of *Fomes lignosus* in Young Rubber Areas", which follows this paper. This scheme has been in operation at the Experiment Station as a routine treatment during the past eight months and, within the

coming year, sufficient data should have accumulated for an estimation of its success to be made. The method has one great advantage over schemes of control based on deep digging in that it is only one step, and that an inexpensive one, beyond the operation of tree-to-tree inspection, and tree-to-tree inspection is absolutely necessary as a preliminary to any type of control measure. This point cannot be too greatly stressed: *It is impossible to plan control measures adequate to deal with an attack of the disease in a given area until the magnitude of the task in hand has been correctly assessed.*

While the scheme has been operating at the Experiment Station, all diseased trees encountered during the root inspections have been treated, whether there has been any hope of saving them or not, and careful records have been kept of the condition of each tree at the time of treatment, so that information may be obtained on the effect of curative treatment on trees in all stages of attack. Scraping away of diseased tissue in the hope of saving trees already penetrated by the fungus has been discarded, for, besides being tedious and expensive, it exposes living tissues to the cauterising action of the fungicide employed, and often leads to the entrance of die-back fungi into the root system. Trees which are penetrated beyond a certain limit at the time of treatment are doomed to die, but trees which have not reached this limit can presumably be cured. Attention has been concentrated on determining this limit, and on finding a suitable periodicity of treatment which will be economically possible, and will ensure that during the interval between one treatment and the next the number of cases passing the danger mark will be a minimum. In order to discover the optimum periodicity, treatment has been carried out on the various fields at the Experiment Station at intervals ranging from one to nine months.

Besides this general investigation, a limited number of more precise experiments have been planned to measure with greater accuracy the efficiency of the scheme, to compare its efficiency with that of other better known schemes, and to compare the efficiency of copper sulphate with that of other well known fungicides. The lay-out of these experiments will now be briefly described ; they are yet too immature to yield results suitable for publication.

*Experiment V.* This experiment was planned to provide a direct measure of the efficiency of the scheme. An 8 acre block, which carried a heavy and evenly distributed attack of *Fomes lignosus,* was divided into halves by a line running east and west. The roots of trees in the whole block are inspected once a month ; in the southern half the scheme has been put into operation while the northern half has been left untreated as a control. This method of controlling the experiment will differentiate between the beneficial effect of copper sulphate treatment and the probable fungicidal action of the sun during root inspection.

*Experiment VI.* Two adjacent 10 acre blocks were chosen in each of which the disease was evenly distributed, and the blocks were divided into halves. The scheme has been put into operation over the whole area, with two-monthly rounds of root inspection and treatment but, in one block, copper sulphate is used as the fungicide in one half and lime-sulphur in the other, and in the other block copper sulphate is used in one half and Uspulun Universal in the other. The concentrations employed are :—copper sulphate 2 per cent., lime-sulphur 1 per cent. (polysulphide sulphur), and Uspulun 0.25 per cent., all in aqueous solution.

This experiment should indicate whether there are any striking differences between the fungicidal properties of these three solutions in controlling the disease.

*Experiment VII.* It is probable that in a swamp area, where the water table is high, the scheme will fail because of the rapid dilution of the fungicidal solutions. An experiment was therefore planned in which a comparison could be made between the effect of the new scheme and the effects of two other more commonly used methods of treatment in controlling the disease under swamp conditions.

A swamp area, 4 acres in extent, bearing an evenly distributed heavy attack of the disease has been divided into three similar subplots on which the following methods of control are being compared :—

(1) Application of lime at the rate of 1 ton per acre scattered over an area of 8 feet square around every tree and forked in (no root inspection).

(2) Treatment of dead trees only, the sites being dug deeply and the buried timber removed (a common method of control).

(3) The new scheme of treatment.

The whole area has recently been deeply drained.

*The Value of Lime in the Control of the Disease.* A digression may be made at this point to discuss the efficiency of lime as a soil fungicide for use against *Fomes lignosus.* At the very first record of the disease (16) quicklime was recommended for the treatment of infected areas and, until recently, the digging of lime into infected soil has been regarded as the standard method of control. Quicklime was recommended on the grounds that :—

(a) it kills the mycelium with which it comes into contact in the soil by direct caustic action.

(b) when in solution in the soil water as calcium hydroxide it renders the soil alkaline, and thus inhibits the growth of the fungus.

It is surprising to learn that lime is still in use on many estates, since Bryce (3) has shown that these hypotheses are quite untenable.

On artificial media, apart from the soil, they are sound, but under field conditions they cease to apply.

When quicklime is incorporated in the soil its cauterising quality is rapidly lost. The lime begins to slake immediately, and the particles of the slaked product soon become coated with a film of calcium carbonate through the action of carbon dioxide in the soil atmosphere. If the soil is strongly acid the film of carbonate is not a disadvantage, but as the soil reaction approaches neutrality the rate of solution of the film is exceeded by its rate of formation, and the soluble hydroxide becomes imprisoned within an ever thickening shell of calcium carbonate. The carbonate has no caustic action on the fungus, neither can it render a soil strongly alkaline because it is so sparingly soluble in water. It is doubtful whether even such large applications as 10 or 20 tons to the acre could carry typical Malayan soils far enough beyond neutrality to justify such treatment.

These considerations alone are sufficient to discredit the reputed efficiency of lime as a soil fungicide in this country, but Bryce (3) has shown an even stronger reason why its use for the control of *Fomes lignosus* should be condemned. The results of his experiments indicate that *the fungus grows most readily on slightly alkaline media, and that it is much more intolerant of acid than of alkaline conditions.* The obvious deduction is that under normal conditions in a typical Malayan soil the growth rate of the fungus is depressed on account of soil acidity, and that the application of lime merely tends to bring the soil into the optimum conditions for the growth of the fungus as far as this factor is concerned, thus increasing instead of diminishing its activity.

Even if no film of carbonate prevented the activity of the hydroxide in rendering soils alkaline, Bryce (3) has shown that it would require an application of lime five times as heavy as that employed in Experiment VII to inhibit the growth of the fungus in the soil. Such an application would cost about $100 per acre, and would probably have a deleterious effect upon the growth of the rubber trees, which prefer a soil medium on the acid side.

It is probable that, in certain circumstances, lime may still be used with profit in the treatment of the disease, e.g. in badly drained swamps where the trees are sickly and offer little resistance to the heavy attacks which often develop in such localities in spite of the depressing effect of the sourness of the soil on the growth of the fungus. Under these conditions it is probable that the beneficial effect of liming (combined with adequate draining) upon the growth of the host plants will outweigh any detrimental effect which may follow the concurrent increase in the activity of the parasite in the soil. It was in order to investigate this point that one of the plots in Experiment VII was treated with lime.

Besides the experiments which are in hand at the Experiment Station, Sungei Buloh, other schemes of control are being tried out under the supervision of the Pathological Division on various estates. These schemes are usually modified by, or adopted from, the particular views of the planters who are engaged in carrying them through, and two of them in particular should yield important results within the coming year.

*Experiment VIII.* On an estate in Kedah, diseased areas in infected fields are being delimited by root inspections primarily of the jungle stumps and secondarily of the rubber trees surrounding the diseased stumps. The areas are then dug deeply and all buried jungle timber is removed. The lateral roots of very large stumps are cut off to the bole and extracted, and the boles are then trenched deeply and allowed to rot in situ. All diseased rubber trees encountered are treated: diseased laterals are cut off if necessary and other infected portions of the root systems, as far as the rhizomorphs extend, are painted with a 1 per cent. lime-sulphur solution. The trees are then staked and left with their root systems exposed to the air for a fortnight, and at the end of this period a second application of the fungicide is made.

*Experiment IX.* On an estate in Johore, diseased areas are being delimited by means of a systematic root inspection of the rubber trees. The larger areas are being deeply dug and the buried timber removed. The digging does not go to the full extent of the buried timber, but to a definite depth, digging to 1½ feet and to 2 feet being experimented with on different areas. Smaller diseased patches, which it is not intended to replant, are merely surrounded by trenches and left alone. Diseased trees encountered during the root inspections are treated with copper sulphate in the normal manner.

These experiments are as yet too immature for a discussion of their results to be attempted.

*Points already established.* The only point which has been definitely established during the short time in which the experiments have been in progress is, that an aqueous solution of copper sulphate at 2 per cent. strength can effectively kill the mycelium of the fungus, under the conditions of the experiments, as long as the two come into direct contact with each other. If the solution has to soak through the soil or through diseased tissue before it reaches the mycelium its fungicidal efficiency is seriously impaired, and its effect cannot be guaranteed.

The treatment with copper sulphate does not appear to be able to cure well-established attacks, but it has already been shown fairly conclusively that, if the treatment is periodic, it is possible to prevent the development of such attacks in hitherto healthy trees.

## (2) Investigation of the Life History of the Fungus *Fomes lignosus.*

In this section an attempt has been made to show that the well-known white rhizomorphs which cause the common root disease of young rubber belong to the fungus *Fomes lignosus* Klotzsch, whose fructifications are so frequently associated with the disease.

*Vegetative comparison of the various Forms of the Fungus.* Pure cultures of a mycelium have been established from each of the following sources :—

(i) The spores of *Fomes lignosus.*
(ii) The substance of the fructification of *Fomes lignosus.*
(iii) The white rhizomorphic strands enveloping a root killed by the disease attributed to *Fomes lignosus.*
(iv) White rhizomorphic strands obtained in the laboratory from a diseased root kept under moist conditions.
(v) The junction between healthy and diseased wood in a root of a diseased tree.

(i) It was feared for many months that it would be impossible to obtain pure cultures from spores, as fructifications examined at intervals proved to be repeatedly sterile. During the early part of December 1931 however there was heavy and continuous rain, and on December 21st it was reported that fructifications were being produced in profusion from the sides of isolation trenches at the Experiment Station.

Specimens of these fruits were obtained and on examination proved to be sporing freely. On some specimens the pores were 1 cm. long and sporing throughout their whole length, while spores could be found in the very youngest pores only just differentiated from the smooth outer rim of the fructification.

Spore measurements agreed closely with those given by Steinmann (21) for the species occurring in the Netherlands East Indies. They were as follows :—

Pores bright orange brown, 80$\mu$ in diameter, and up to 1 cm. long.

Basidia colourless, 16$\mu$ long, 8$\mu$ in diameter, bearing at their crown four sterigmata, 4-5$\mu$ long, from which were abstricted the spores.

Spores colourless, elongated when young, becoming nearly round when mature, 4-5$\mu$ in diameter.

Cystidia-like bodies were observed, about 20$\mu$ in length but they were not so elongated as those figured by Steinmann (21); in shape they were more like an inverted turnip. They were thin walled and colourless.

Spore deposits were readily obtained and, on being transferred by means of a sterile brush to the surface of corn meal agar in a

a petri dish, the spores germinated readily. After two days 75-100 per cent. of the spores had germinated both in dishes kept in the dark and in those kept in the light.

Profuse bacterial development restricted the growth of the germ tubes at first, but afer 4 or 5 days the colonies seemed to stale, and the fungus grew sufficiently beyond the edges of the colonies for pure cultures to be obtained. Growth was more rapid in the dark than in the light.

Growth on corn meal agar was slow and tenuous and the fungus was therefore transferred to French bean agar, as recommended by Bryce (3) in his cultural studies of the fungus. On this medium growth was rapid and profuse, and the medium has been used in all subsequent cultural work.

Fructicifications from rotting jungle timber, from the stump of a rubber tree, and from the stump of a Rain Tree (*Pithecolobium Samam*) have been examined weekly since the spores were first found, and all fructifications have proved to be fertile. The vigour of growth of the fructifications is now falling off and, with it, the rate of sporing. It is now difficult to obtain material for making spore deposits, and only the younger parts of the sporophores are suitable.

(ii) In order to obtain cultures from a fructification, pieces were cut from the substance of the pileus with a sterile knife and placed on corn meal agar. Growth began immediately, the same tenuous silky mycelium being obtained as in the spore cultures. When transferred to French bean agar, rapid and profuse growth took place.

(iii) Pieces of fresh, vigorous rhizomorphs were taken from the surface of the roots of a young tree showing typical systems of root disease. They were washed repeatedly in sterile water and placed on the surface of French bean agar. On the following day silky strands of mycelium could be seen growing from the broken ends of the pieces of rhizomorph, but in every culture except one the growth of the mycelium was retarded by contamination with moulds and bacteria. In one culture however contamination did not occur and pure cultures were easily obtained from this tube.

(iv) Cultures were similarly established from rhizomorphs growing from diseased roots kept moist in a jar at the laboratory.

(v) Cultures of the mycelium permeating diseased wood were obtained by cutting shavings with a sterile knife from the junction between healthy and diseased wood taken from a specimen of a root in the early stages of attack. The shavings were lightly flamed and transferred to corn meal agar and a number of isolations of apparently identical mycelia was obtained. These cultures were established in June 1931 and have been preserved in culture on corn

meal agar. When transferred to French bean agar the same change from a slow tenuous to a rapid vigorous growth was obtained.

When these five different mycelia had become well established on French bean agar, several cultures of each were made on the same day from mycelia in apparently the same stage of development. Vegetative comparison of the cultures showed that (ii), (iii), (iv) and (v) were apparently identical, and that (i) was differentiated from the others only in showing slightly slower, closer textured growth, with the production of much aerial mycelium.

*Cultivation of the Rhizomorphs in the Laboratory.* On two occasions pieces of diseased root have been placed in a glass jar with water and kept in the dark. In each case white rhizomorphic strands have sooner or later appeared, and have grown in great profusion over the inner surface of the glass. Growth has always been most rapid when fresh water has been added to the cultures, especially if they have been allowed to dry out for some time previously. These rhizomorphs are apparently identical with those found in the field, being at first white, later yellowish, and sometimes a deep reddish brown where they are in contact with the glass. It was from one of these cultures that the culture (iv) was established.

*Cultivation of the Fructifications in the Laboratory.* As a control to the above experiment, another culture was prepared and kept in the light. A little growth of rhizomorphs occurred, but soon rudimentary fructifications made their appearance. These however never matured, and became smothered by other fungi.

The effect of light in stimulating sporophore formation was further demonstrated when a two-months-old rhizomorph culture was exhibited at the Malayan Agri-Horticultural Exhibition in August 1931. After standing three days in the light, numerous small fructifications began to appear. On returning the culture to a dark chamber after the Exhibition, sporophore formation immediately ceased, and the young fruit bodies degenerated. At the beginning of January 1932, however, when the culture was once more exposed to the light, new fructifications rapidly developed, and on January 15th, less than a fortnight after re-exposure, they were found to be bearing spores.

Attempts to obtain rudimentary fructifications from pure cultures on rubber wood have so far proved entirely abortive. The fungus develops quite freely in a vegetative manner, but neither of the cultures has yet shown a tendency to form fruits when placed in the light.

*Conclusions.* In this preliminary report no formal conclusions will be drawn from the results already yielded by the experiments carried out under this section of the investigation.

It may be stated, however, that all evidence collected up to the present time tends to show that the causal organism of the common

disease of young rubber is the fungus *Fomes lignosus* Klotzsch, or at least is the fungus to which this name has been applied in eastern rubber plantations.

## Summary.

(1) Up to an age of three years, rubber trees are exposed to a greater risk of infection from *Fomes lignosus* in an area from which surface timber and jungle stumps have been removed than in an uncleared area.

(2) It is probable that the incidence of the disease in a young clearing is less under a cover crop than in clean weeded areas.

(3) Up to the age of three years the incidence of the disease on rubber trees is probably least where secondary jungle is allowed to grow as a natural cover.

(4) An aqueous solution of copper sulphate at a 2 per cent strength is able to kill superficial mycelium upon the roots of rubber trees if it comes into direct contact with the mycelium.

(5) Fructifications of *F. lignosus* spore freely at certain seasons, which probably occur after periods of heavy and continuous rain, and the spores are easily germinated in water and on nutrient agar.

(6) In macroscopical vegetative characters the mycelia isolated in pure culture on nutrient agar from the fructifications, from rhizomorphs and from diseased wood are identical, and the mycelium from spore cultures is of a very similar type but has a rather slower growth rate and produces much aerial mycelium.

(7) Rhizomorphs and fructifications can be obtained under experimental conditions in the laboratory from naturally infected material. The most profuse rhizomorph formation takes place in the absence of light: when exposed to the light there is a tendency to form fructifications.

(8) Fructifications as obtained in (7) can produce spores even in the very early stages of development.

## Acknowledgment.

The writer wishes to record his indebtedness to Mr. A. Sharples, Head of the Pathological Division, for continual help and advice during the course of the investigations; also to those planters who have given time and assistance in carrying out certain of the large scale experiments.

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# A SCHEME OF TREATMENT FOR THE CONTROL OF FOMES LIGNOSUS IN YOUNG RUBBER AREAS.

BY

R. P. N. NAPPER.

*Fomes lignosus* causes root disease in rubber plantations of all ages, but the attack of the fungus is most virulent and causes most severe loss of stand between the second and the fifth year. It sometimes happens in a clearing, the age of which lies within these limits, that the depredations of the fungus rise to an alarming extent within a short space of time, and that the planter is faced with the problem of deciding what immediate steps he should take in order to prevent serious loss of stand.

In the following paragraphs a scheme of treatment is outlined for use in the control of attacks of all degrees of severity. The scheme has been drawn up after careful consideration of every phase of the problem in the light of certain experimental data which have recently come to hand, and has been in operation at the Institute's Experiment Station as a normal routine treatment for the past six months. It is early yet for a final statement to be made, but the experimental results which have so far been obtained justify the recommendation of the scheme for use on estates.

The first essential operation in dealing systematically with an attack of *Fomes lignosus* is a careful tree-to-tree inspection over the whole infected area. It is necessary that every tree should be thoroughly examined at the collar and for one to two feet along the laterals and six to eighteen inches down the tap root (depending on the size of the tree), and that, at the appearance of the slightest trace of the white strands characteristic of the fungus, the tree should be marked for treatment. It is advisable also to mark for treatment trees whose roots carry any other type of suspicious white markings, for there is evidence that the mycelium of the fungus can aggregate itself on the surface of roots in forms other than that of the typical "Fomes strands."

This tree-to-tree inspection is justified by the fact that, without it, it is impossible to make an accurate estimate of the distribution and extent of the disease, and hence impossible to draw up a control scheme commensurable with the requirements of the task to be performed.

Marked trees will fall into two main classes :—

(a) Trees which *can* be detected without root examination.

(b) Trees whose foliage still looks healthy, and which *cannot* be detected without a root examination.

Class (a) includes the trees which are already dead, and those whose leaves have acquired a sickly appearance.

Class (b) includes trees falling into two further subdivisions :—

(b1) Trees whose foliage still looks healthy but whose root systems are more or less attacked by the fungus.

(b2) Trees which bear external mycelium on their roots, but into whose tissues the fungus has not yet penetrated.

Trees in class (a) should be removed at once, and upon the thoroughness with which this operation is performed depends largely the ultimate success of the scheme. The roots of these trees should be followed up to their extremities and completely removed. Subsequent treatment of the sites will depend upon the planting and thinning out programmes.

If the hole is not to be replanted a trench should be put round it beyond the limits of the root range of the diseased tree, or beyond the source of infection, whichever is further from the hole. The trench should be two feet deep and a changkol wide and, if it is kept open, and if the roots of neighbouring trees are prevented from passing beyond it, it should be sufficient in itself to prevent spread of the disease from the infected site. Infection can remain dormant in the soil, however, for a considerable period of time, and there is always the risk in later years that the roots of surrounding trees will pass through or under the trench and will become infected, thus rendering the trench useless as a measure of control. It is safer to dig over the infected site to two feet, removing all buried timber and exposing the soil thoroughly to the sun, before the trench is made. All trenches dug to effect control of root diseases should be kept regularly cleaned out; if they are allowed to silt up, or if cover crop is allowed to grow across them, they become useless, and the labour spent on making them is wasted.

If the holes are to be replanted, the sites should always be dug over. It has been found that the following recommendations can be employed as a matter of routine in the treatment of the sites of dead trees up to 4 years of age :—

The tree should be removed completely, both the tap root and laterals being followed to their extremities and completely extracted, and the soil should be dug thoroughly to a depth of three feet within a circle of 8 feet in diameter about the site of the tree. Then a trench should be marked out 15 to 20 feet square (depending on the size of the tree) around the diseased area, and, between the trench and the deeply dug area, the soil should be dug to 18 inches and all timber removed. More deeply buried timber which is exposed during

this operation should be followed down and extracted. Finally the trench should be dug around the area to a depth of 2 feet, the soil being thrown towards the centre. This trench is intended to prevent infection from outside entering the treated area through the soil.

It seems probable that the most effective method of killing the mycelium of *Fomes lignosus* is to expose it to the action of light and desiccation. This can be effected by thorough cultivation, but it is impossible to expose every particle of soil to the action of the sun at one changkolling, and a succession of two or three cultivations at three-monthly intervals, although effective, means a considerable loss of time. It is recommended therefore that the central hole should be drenched with a fungicide when digging operations have been completed. It is most satisfactory to allow an interval of about a month to elapse between digging and drenching, so that any mycelium dormant in the soil may have an opportunity of renewing its activity and thus becoming more susceptible to injury by the fungicide, but this interval can be dispensed with and digging, drenching, and supplying, may follow on successive days. On the Experiment Station the fungicide at present in use is copper sulphate, which is applied at the rate of 5 gallons of a 2 per cent solution over the central deeply dug area.

The application of lime to the soil, with the object of reducing the activity of *Fomes lignosus,* may be regarded as a waste both of time and capital.

The treatment of trees falling in class (b) is of great importance in checking the spread of the fungus and in delimiting the areas of infection. It is rarely possible to detect signs of the disease in the roots by an observation of the aerial portions of a diseased tree until the tree is in an advanced stage of attack, and observations on the number of dead or sick trees in an area gives no indication of the distribution and extent of the disease. Treatment of individuals in this class, as in class (a), is influenced by the thinning-out programme, for if trees can be spared from the stand it will be as well to remove those of sub-class (b1) which are most heavily infected in the roots, treating them as belonging to class (a). It is doubtful whether any external treatment can be sufficiently penetrative to save a tree which is on the border line between classes (b) and (a).

Methods of treating trees in class (b) by the application of a fungicide as a liquid or a paint to the collar and the affected laterals, after the removal (and destruction) of as much as possible of the external mycelium, appear to be yielding satisfactory results. The treatment which is at present in use on 1—3 years old areas at the Experiment Station, is a drenching at the collar with 1 gallon of a 2 per cent solution of copper sulphate. The infected trees are treated as soon as possible after the root inspection and very little extra

digging is involved. The root systems are opened up until the whole extent of the mycelium on them is exposed, and the source of the mycelium is discovered if possible and removed. The solution is then poured into the earth cavity, and while it is still standing around the roots it is rubbed *gently* over the infected surfaces with the hand. In the treatment of older trees the volume of fungicide used per tree will have to be increased.

As an alternative method of treating class (b) cases, one estate reports favourable results with lime-sulphur solution. This has been applied at a strength of 1 per cent. (polysulphide sulphur) as a paint to infected roots. The lime-sulphur solution is made up as follows * :—

> " 14 ozs. of quicklime are slaked and a little more water is added to make milk of lime. The mixture is strained and 35 ozs. of flowers of sulphur are stirred in and the mixture is diluted to one gallon by addition of water.
>
> " The mixture is boiled for one hour and the upper clear liquid is decanted from the sludge. The liquid thus prepared contains about 10 per cent. of polysulphide sulphur.
>
> "A 1 per cent. polysulphide mixture is obtained by diluting to 10 gallons with water."

Lime sulphur is an unsuitable substance and it is not at present recommended for application to the soil in the treatment of trees falling in class (a).

It is not anticipated that one round of treatment on the lines of the above scheme will give effective control in a heavily diseased area. The treatment should be periodic. It has been observed that the mycelium of the fungus lives more or less epiphytically upon the bark for a certain length of time before penetration takes place. If therefore periodic rounds of treatment are put into operation at intervals which are less than the time it takes for the epiphytic mycelium to effect penetration, it should be possible to avoid the establishment of the disease in previously unaffected trees. From the results of experimental work already carried out, successive treatments at intervals of two or three months seem to be sufficiently effective for practical purposes even in heavily diseased areas. It may require two or three rounds of treatment at three-monthly intervals to gain control over a well-established attack, and two further treatments at six-monthly intervals may be necessary in extreme cases to keep the incidence low until the activity of the fungus naturally abates.

If the establishment of fresh cases can be prevented until this natural abatement takes place (usually in the fifth or sixth year),

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* Beeley, F., Quarterly Journal of Rubber Research Institute, Vol. **2**, No. 4, p. 216, April 1931.

and until the rubber trees are old enough to offer determined resistance to the disease, then successful control will have been obtained. It is hoped that such control will be effected by the above scheme. The scheme has not been in use for a sufficiently extended period to enable the Institute to recommend it with absolute confidence, but within the space of twelve months it is hoped that sufficient data will have accumulated to enable such a recommendation to be made. In the meanwhile intensive experimental work is being carried out, and the evidence of the results already available appears strong enough to justify the presentation of the foregoing scheme of control as a practical proposition.

A brief analysis of the costs of applying these control measures on the Experiment Station is given below. These include cost of labour and material but not of supervision and are given as costs per round of treatment, not as costs per annum. The soil is sandy and easily worked, and costs will be higher on heavier land.

*Tree-to-Tree Inspection (100 trees per acre).*

2 years' old rubber ... 15—20 cents per acre.
3 years' old rubber ... 30—50 cents per acre.

*Treatment of trees in class (a).*

In unstumped areas ... 70—110 cents per tree.
In stumped areas ... 60— 90 cents per tree.

*Treatment of trees in class (b).*

2 years' old rubber ... 6— 8 cents per tree.
3 years' old rubber ... 6— 11 cents per tree.

The need for the immediate publication of a recommendation for the treatment of attacks of *Fomes lignosus* in young rubber areas has been shown by the number of inquiries recently received from estates asking for information on the subject. It is hoped that the foregoing paragraphs will answer the majority of questions which will arise in the immediate future in this connection, but the recommendation must be regarded as provisional only, pending the results of experiments already in hand.

# SOME VARIATIONS OF BUDDING TECHNIQUE ON BIG STOCKS.

BY

C. C. T. Sharp.

These observations were taken on a square block of light sandy soil on the Experiment Station at Sungei Buloh planted in February 1929 with seed at stake. At the beginning of the experiment the mean girth of the trees at the collar was 12.5 inches.

It was intended to test (1) whether the use of immature budwood on large stocks would have any effect on the number of successful buddings obtained; (2) whether a higher proportion of successes could be obtained by extending the period before opening beyond the normal 18-20 days; and (3) whether either or both of these departures from the normal budding practice would have any effect on the rate at which the buddings would begin to shoot.

## Plan of the Experiment.

The block was divided into five strips of five rows of approximately 30 trees. For reasons not connected with this experiment each of the five rows of each strip was budded at a different height, viz., at ground level, 1 foot, 2 feet, 3 feet and 4 feet. This rendered any more precise layout impracticable but the experiment was arranged in such a way that every plot contained an equal proportion of trees budded at each height. Each strip was budded with a single clone, the clones used being Bodjong Datar 5, AVROS 152, Sungei Reko 9, AVROS 50 and Prang Besar 186.

The budwood which was cut at intervals throughout the day and was used as soon as possible after cutting was divided into three parts according to its degree of maturity.

(a) *Brown Wood.* Fully matured wood with no trace of green bark on it.

(b) *Intermediate Wood.* Wood on which the formation of cork had started but had not been completed: and

(c) *Green Wood.* Wood on which the only cork formed was to be found in small patches around the leaf scars, the whole of the internodes being quite green.

The trees were all budded on the same day, the buddings being opened in three groups after 18, 23 and 28 days. All were

cut back to four inches above the patch on the same day—the fortieth after budding.

The details of the layout of the experiment are shown in Fig. 1.

Five coolies were employed, each coolie budding one row of each clone.

The plots within the experiment were arranged in such a way that there was no significant difference between the mean girths of the trees contained in each treatment.

*Results.* Table I gives a summary of the results at opening and at cutting back.

### Time of Opening.

At the time of cutting back the mean proportion of successes was 78 per cent. Examination of columns 6 and 11 shows that in the former all the percentages of successes except two were lower than the general mean and in the latter all but five were higher than the general mean. Taking the total percentages of successes the difference between 69 per cent., and 82 per cent., is undoubtedly significant and shows that a definite advantage of 13 per cent., is obtained by postponing the time of opening to 23 days after budding, though there appears to be little if any advantage in extending the time any further.

The figures given of the total percentage of successes in columns 4 and 13 of Table III show that this is true of each of the clones used in the experiment.

### Age of Budwood.

In column 17 of Table I the total percentage of final successes for each clone will be found. The use of green wood and intermediate wood produces very similar results. With the exception of BD 5 there is in every case a definite advantage to be obtained by the use of brown wood, this being the most marked in the case of AVROS 152. With BD 5 there was under the conditions of this experiment no advantage to be obtained by using brown wood, the percentage of successes for all three types of wood being approximately the same in each case.

### Time of Shooting.

Table II shows the numbers of buddings that had shot 21, 50, and 72 days after cutting back for each kind of budwood and also the percentage of growing bud shoots to buddings made.

It will be seen that 21 days after opening 41 per cent., of the buddings made with green wood had shot compared with 27 per cent., of those made with brown wood. This difference is caused almost entirely by the slowness of shooting of buddings made from brown wood of AVROS 50 and BD 5, two clones which under normal conditions are characteristically late in branching. The immaturity of the wood has a smaller effect on the other three clones which are normally of an earlier branching habit. After 72 days the number of buddings shot was approximately equal for each type of budwood used. In spite of the larger number of failures obtained when green wood was used, the percentage of buddings shot to buddings made for green, intermediate and brown wood were 62, 59 and 61 per cent., respectively.

Table III shows the number of buds that had shot 21, 50 and 72 days after cutting back in the three groups opened at 18, 23 and 28 days.

The first effect of delaying the time of opening was to postpone the time of shooting, comparison of column 6 and 24 showing that in the case of every clone a larger percentage of buddings had shot after the shorter period although the number of successes was smaller. Fifty days after cutting back the numbers of dormant buds in the 18, 23 and 28 day groups were 37, 67 and 48 respectively, but the percentage of buddings shot to buddings made was 54, 54 and 64. This indicates that any delay in shooting that arises from postponing the time of opening is of a temporary nature and is insufficient to counteract the advantages of the higher percentage of successes obtained by increasing the time of opening to 23 days, and that a further postponement of the time of opening to 28 days may bring an even further advantage in the case of certain clones.

## Summary and Conclusions.

1. The effect of lengthening the time of opening and of using budwood of different degrees of maturity has been investigated.

2. The results obtained apply (i) only to large stocks, the trees budded being 32 months old with a mean girth of 12.5 inches, and (ii) under conditions in which any delay that occurs between the cutting and using of budwood can be reduced to a minimum.

3. Clones BD 5, AVROS 152, SR 9, AVROS 50 and PB 186 were used.

4. By increasing the period before opening from 18 to 23 days the percentage of successes was increased from 69 to 82.

5. No advantage was obtained by extending the period before opening to 28 days.

6. Fully matured budwood gave a higher proportion of successes than immature wood except in the case of BD 5 where immature wood gave as good result as the mature wood.

7. The time elapsed before the buds shot was much reduced in the case of AVROS 50 and BD 5 by the use of green budwood. There was no corresponding reduction with the other clones used.

8. Opening after 23 days delayed the time of shooting but the delay was insufficient to counteract the advantage of the greater number of successes.

9. There is an indication that opening after 28 days will tend to reduce still further the number of buds that remain dormant for a long time after cutting back, but this cannot be demonstrated with certainty from this experiment.

Fig. I. Layout of the Experiment.

| Clone BD 5 | Green Budwood | | | Intermediate Budwood | | | Brown Budwood | | |
|---|---|---|---|---|---|---|---|---|---|
| AV 152 | Intermediate. Budwood | | | Brown Budwood | | | Green Budwood | | |
| SR 9 | Brown Budwood | | | Green Budwood | | | Intermediate. Budwood | | |
| AV 50 | Green Budwood | | | Intermediate. Budwood | | | Brown Budwood | | |
| PB 186 | Intermediate. Budwood | | | Brown Budwood | | | Green Budwood | | |
| Time of opening Days | 18 | 23 | 28 | 18 | 23 | 28 | 18 | 23 | 28 |

## TABLE I.

### Analysis of Budding Results.

| Clone 1 | | | Opened after 18 days | | | | | Opened after 23 day | | | | | Opened after 28 days | | | | | 17 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | 2 No. budded | 3 Success at opening. | | 5 Success at cutting back | 6 | 7 No. budded | 8 Success at opening | 9 | 10 Success at cutting back | 11 | 12 No. budded | 13 Success at opening | 14 | 15 Success at cutting back | 16 | Total final Successes |
| | | | | No. | % | No. | % | | No. | % | No. | % | | No. | % | No. | % | % |
| Green Budwood | BD | 5 | 15 | 15 | 100 | 11 | 73 | 15 | 15 | 100 | 14 | 93 | 20 | 17 | 85 | 17 | 85 | 84 |
| | AV | 152 | 20 | 19 | 95 | 12 | 60 | 14 | 13 | 93 | 10 | 71 | 15 | 11 | 73 | 10 | 67 | 65 |
| | SR | 9 | 15 | 15 | 100 | 9 | 60 | 18 | 16 | 89 | 13 | 72 | 14 | 13 | 93 | 11 | 79 | 70 |
| | AV | 50 | 15 | 14 | 93 | 8 | 53 | 15 | 15 | 100 | 14 | 93 | 18 | 17 | 94 | 15 | 83 | 77 |
| | PB | 186 | 20 | 15 | 75 | 12 | 60 | 15 | 15 | 100 | 14 | 93 | 15 | 14 | 93 | 13 | 87 | 78 |
| | Total | | 85 | 78 | 92 | 52 | 61 | 77 | 74 | 96 | 65 | 84 | 82 | 72 | 88 | 66 | 80 | 75 |
| Intermediate Budwood | BD | 5 | 15 | 14 | 93 | 11 | 73 | 19 | 18 | 95 | 17 | 89 | 15 | 15 | 100 | 15 | 100 | 88 |
| | AV | 152 | 15 | 15 | 100 | 9 | 60 | 15 | 13 | 87 | 12 | 80 | 19 | 15 | 79 | 12 | 63 | 67 |
| | SR | 9 | 19 | 18 | 95 | 13 | 68 | 14 | 13 | 93 | 11 | 79 | 15 | 13 | 87 | 12 | 80 | 75 |
| | AV | 50 | 11 | 10 | 91 | 8 | 73 | 18 | 16 | 89 | 13 | 72 | 15 | 14 | 93 | 12 | 80 | 75 |
| | PB | 186 | 13 | 12 | 92 | 12 | 92 | 15 | 11 | 73 | 9 | 60 | 18 | 17 | 94 | 15 | 83 | 78 |
| | Total | | 73 | 69 | 95 | 53 | 73 | 81 | 71 | 87 | 62 | 76 | 82 | 74 | 90 | 66 | 80 | 76 |
| Brown Budwood | BD | 5 | 19 | 19 | 100 | 13 | 68 | 13 | 11 | 85 | 11 | 85 | 15 | 15 | 100 | 13 | 87 | 82 |
| | AV | 152 | 14 | 13 | 93 | 10 | 71 | 20 | 19 | 95 | 17 | 85 | 15 | 15 | 100 | 15 | 100 | 86 |
| | SR | 9 | 14 | 13 | 93 | 8 | 57 | 15 | 14 | 93 | 13 | 87 | 20 | 20 | 100 | 17 | 85 | 78 |
| | AV | 50 | 19 | 19 | 100 | 18 | 95 | 15 | 14 | 93 | 13 | 87 | 14 | 13 | 93 | 12 | 86 | 90 |
| | PB | 186 | 15 | 13 | 87 | 11 | 73 | 18 | 18 | 100 | 16 | 89 | 15 | 15 | 100 | 15 | 100 | 88 |
| | Total | | 81 | 77 | 95 | 60 | 74 | 81 | 76 | 94 | 70 | 86 | 79 | 78 | 99 | 72 | 91 | 84 |
| Grand Total | | | 239 | 224 | 94 | 165 | 69 | 239 | 221 | 93 | 197 | 82 | 243 | 224 | 92 | 204 | 84 | 78 |

TABLE II.

Time of Shooting as affected by Different Types of Budwood.

| | Green Wood. | | | | | | | | | Intermediate Wood. | | | | | | | | | | Brown Wood. | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 | 19 | 20 | 21 | 22 | 23 | 24 | 25 | 26 | 27 | 28 | | |
| Clone | No. budded. | Success at cutting back. | | After 21 days' Buds Shot | | After 30 days. Buds Shot | | After 72 days. Buds Shot | | No. budded | Success at cutting back | | After 21 days. Buds Shot | | After 30 days. Buds Shot | | After 72 days. Buds Shot | | No. budded | Success at cutting back | | After 21 days. Buds Shot | | After 30 days. Buds Shot | | After 72 days. Buds Shot | | | |
| | | No. | per cent | No. | per cent | No. | per cent | No. | per cent | | No. | per cent | No. | per cent | No. | per cent | No. | per cent | | No. | per cent | N . | per cent | No. | per cent | No. | per cent | | |
| BD 5 | 50 | 42 | 84 | 20 | 40 | 30 | 60 | 31 | 62 | 49 | 43 | 88 | 25 | 51 | 31 | 63 | 33 | 67 | 47 | 37 | 82 | 3 | 6 | 23 | 49 | 27 | 57 | | |
| AV 152 | 49 | 32 | 65 | 21 | 43 | 28 | 57 | 28 | 57 | 49 | 33 | 67 | 21 | 43 | 29 | 59 | 29 | 59 | 49 | 42 | 86 | 18 | 37 | 27 | 53 | 28 | 57 | | |
| SR 9 | 47 | 33 | 70 | 17 | 36 | 26 | 55 | 27 | 57 | 48 | 36 | 75 | 16 | 33 | 29 | 60 | 30 | 62 | 49 | 38 | 78 | 18 | 37 | 24 | 49 | 28 | 57 | | |
| AV 50 | 48 | 37 | 77 | 21 | 44 | 30 | 62 | 30 | 62 | 44 | 33 | 75 | 9 | 20 | 14 | 32 | 15 | 34 | 48 | 43 | 90 | 8 | 17 | 23 | 48 | 26 | 54 | | |
| PB 186 | 50 | 39 | 78 | 21 | 42 | 35 | 70 | 36 | 72 | 46 | 36 | 78 | 22 | 48 | 31 | 67 | 33 | 72 | 48 | 42 | 88 | 19 | 40 | 35 | 73 | 38 | 79 | | |
| All Clones | 244 | 183 | 75 | 100 | 41 | 149 | 60 | 152 | 62 | 236 | 181 | 77 | 93 | 39 | 134 | 57 | 140 | 59 | 241 | 202 | 83 | 66 | 27 | 131 | 54 | 147 | 61 | | |

## TABLE III.

Time of Shooting as affected by different periods of opening.

| | Opened after 18 days | | | | | | | | | Opened after 23 days | | | | | | | | | | Opened after 28 days | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 | 19 | 20 | 21 | 22 | 23 | 24 | 25 | 26 | 27 | 28 | | |
| Clone | No. budded. | Success at cutting back. | | After 21 days Buds Shot. | | After 30 days Buds Shot | | After 72 days. Buds Shot | | No. budded | Success at cutting back | | After 21 days. Buds Shot | | After 30 days. Buds Shot | | After 72 days Buds Shot | | No. budded | Success at cutting back | | After 21 days Buds Shot | | After 50 days. Buds Shot | | After 72 days. Buds Shot | | | |
| | | No. | per cent | No. | per cent | No. | per cent | No. | per cent | | No. | per cent | No. | per cent | No. | per cent | No. | per cent | | No. | per cent | No. | per cent | No. | per cent | No. | per cent | | |
| BD 5 | 49 | 35 | 71 | 15 | 31 | 26 | 53 | 27 | 55 | 47 | 42 | 89 | 18 | 38 | 25 | 53 | 27 | 57 | 50 | 45 | 90 | 15 | 30 | 33 | 66 | 37 | 74 | | |
| AV 152 | 49 | 31 | 63 | 22 | 45 | 26 | 53 | 26 | 53 | 49 | 39 | 79 | 18 | 37 | 30 | 61 | 30 | 61 | 49 | 37 | 76 | 20 | 41 | 27 | 55 | 29 | 59 | | |
| SR 9 | 48 | 30 | 63 | 18 | 37 | 24 | 50 | 24 | 50 | 47 | 37 | 79 | 17 | 36 | 23 | 49 | 32 | 68 | 49 | 40 | 82 | 16 | 33 | 32 | 65 | 29 | 59 | | |
| AV 50 | 45 | 34 | 76 | 14 | 31 | 21 | 47 | 23 | 51 | 48 | 40 | 83 | 11 | 23 | 19 | 40 | 19 | 40 | 47 | 39 | 83 | 13 | 28 | 27 | 57 | 29 | 62 | | |
| PB 186 | 48 | 35 | 73 | 25 | 52 | 31 | 65 | 31 | 65 | 48 | 39 | 81 | 21 | 44 | 33 | 69 | 34 | 71 | 48 | 43 | 90 | 16 | 33 | 37 | 77 | 42 | 88 | | |
| All Clones | 239 | 165 | 69 | 94 | 39 | 128 | 54 | 131 | 55 | 239 | 197 | 82 | 85 | 36 | 130 | 54 | 142 | 59 | 243 | 204 | 84 | 80 | 33 | 156 | 64 | 166 | 68 | | |

# TAPPING—THE EFFECT OF SUNDAY RESTS

BY

B. J. Eaton & L. E. Morris.

During 1930 discussion arose concerning the cessation of tapping on Sundays. It was suggested that resting trees on Sundays would reduce the output of rubber by one seventh, but opinions varied, and it was a moot point whether the extra rest day would benefit the trees and so reduce the loss in crop below one seventh, or by disturbing the tapping system would increase it.

Letters were sent to District Planters' Associations, but no data of sufficient value could be obtained, though several estates gave some figures from previous periods with Sunday rest.

A number of estate managers agreed to carry out experiments to compare the results of the usual continuous alternate daily tapping and not tapping on Sundays—on one or more tasks for a period of one year. Unfortunately, owing to leave, staff reductions and so on, it was possible to collect from only six estates records of sufficient length to justify the formation of definite conclusions. These few estates however represent a variety of conditions, which are summarised in Table 1.

Table 1. General Conditions on Experimenting Estates.

| Estate | Locality | Age of Trees in 1930 | Stand per acre | Approx yield lbs p. acre | Number of Control Tasks | Number of Exp'mental Tasks. | Number of Trees p. Task. |
|---|---|---|---|---|---|---|---|
| B | Selangor | 17 | 65 | 1100 | 2 | 2 | 245 |
| C | do | 17 | | | 2 | 2 | 260 |
| J Section A | Kedah | 14 | 151 | 630 | 2 | 2 | 300 |
| Section C | | 14 | 97 | 460 | 2 | 2 | 300 |
| K | Malacca | 7 | 104 | 370 | 1 | 2 | 360 |
| M | do | 22 | 92 | 540 | 1 | 1 | 275 |
| S | Selangor | 21 | 55 | 650 | 3 | 3 | 213 |

The estates are situated in different States, the age of the trees at the start of the experiment varied from 7 to 22 years, the number of trees per acre from 55 to 151, the number of trees per tapping task from 213 to 360, and the yield per acre (reckoned from the experimental tasks) from about 400 to 1100 pounds per year.

## Results.

Records were received monthly and the totals for each estate are given in Table 2.

Table 2. General Results.

| Estate | Duration months | No. of tasks each | System | Alternate daily Tasks. | | Sunday Rested Tasks | | Sunday Rested Task-Loss. | |
|---|---|---|---|---|---|---|---|---|---|
| | | | | Total Crop lbs. | No. of Tappings | Total Crop lbs. | No. of Tappings | Crop as per cent of control | Tappings as per cent of control |
| B | 14 | 2 | 1 | 9687 | 409½ | 8492 | 354½ | 12.34 | 13.42 |
| C | 12 | 2 | 1 | 4333 | 355 | 3573 | 304 | 17.5 | 14.45 |
| J Section A. | 6 | 2 | 2 | 1248 | 161 | 1142 | 139 | 8.5 | 13.7 |
| Section C. | 6 | 2 | 2 | 1418 | 171 | 1474 | 152 | 4.0 gain. | 11.1 |
| K | 12 | 1 | 1 | 1277 | 165 | 1092 | 143 | 14.5 | 13.3 |
| | | | 2 | | | 1125 | 144 | 12.0 | 12.7 |
| M | 5 | 1 | 2 | 670 | 67 | 606 | 56 | 9.6 | 16.4 |
| S. | 12 | 3 | 2 | 7566 | 179 | 6037 | 133 | 20.2 | 25.7 |
| Mean. | | | | | | | | 11.3 | 15.1 |

The general result of the experiments is that the average loss of crop is slightly less than the proportional reduction in the number of tapping days.

However, owing to variations of rainfall and other factors the actual numbers of tappings and rests varies considerably from one estate to another, and though simple addition of the monthly records gives an average result it does not throw much light on the reaction of the trees to the extra rest days. The figures have therefore been analysed further.

## Control and Experimental Tasks.

On each estate from one to four experimental tasks, which were rested on Sundays, were compared with the same number of control tasks which were tapped continuously on alternate days. Control and experimental tasks were arranged alternately side by side or divided between two sections of the estate tapped on alternate days. Where conditions were definitely different, as on estate J, the sections have been treated separately in the analysis of results.

Even with adjacent tasks there may be considerable differences in intrinsic yielding ability. For example on estate B four adjacent tasks were used, the first pair (A) was tapped on alternate days, the second pair (B) was rested on Sundays, and in seven months' tapping the crop from the second pair was 25 per cent., less than that of the first. The whole area was then rested for 5 months according to the A B C system. Afterwards the "A" tasks were rested on Sundays and the "B" tasks were tapped continuously, but the "A" tasks still gave 2.9 per cent., more crop than the "B." Thus there is a definite difference between the yielding capacity of the pairs of tasks, though they are side by side on flat land and apparently similar.

On estate C any such differences were balanced by monthly changes. Two tappers tapped a pair of tasks in Block O on one day and a pair of tasks in Block S, with similar conditions, on the next. In one month, tapper A tapped on Sundays but B did not; in the next month A rested and B tapped on Sundays.

On estate K one control and one experimental task were tapped for 9 months and then changed round for 3 months. The second experimental task was kept on the same system. The yields of the three plots are close enough to justify straight forward addition of crops for the whole year.

On the other estates the tasks were not changed, though on estate J the tappers were varied irregularly.

## Systems of Resting.

Two alternate methods for the arrangement of tapping days were suggested.

In Method 1 a task that is tapped on Monday, Wednesday and Friday is rested on Sunday and tapped again on Monday in the next week. Thus it is tapped on the same days in each week, and in each month (four weeks) there are four periods of two days' rest (Saturdays and Sundays; or-with Tuesday, Thursday and Saturday tapping—Sundays and Mondays) and 12 tapping days compared with 14 on the continuous alternate daily system.

In Method 2 a task that is tapped on Monday, Wednesday and Friday is rested on Sunday, and tapped again on Tuesday, that is when it is due for tapping on the regular alternate daily system. Tapping is repeated on Thursday and Saturday. Sunday fits in as an ordinary alternate rest day, and tapping is continued on Monday, Wednesday and Friday again. Thus in each month there are two periods of three rest days, and again 12 tapping days.

In practice the regular rotation is upset by rainy days and holidays and the actual number of tappings of control and rested tasks are not in this theoretical proportion of 14: 12, or 14.3 per cent., of rests.

Method 1 was employed on estates B and C, and Method 2 on estates J, M and S. On estate K a separate task was tapped on each system.

In Method 1 the regular rhythm of tapping is disturbed every week, and after every third tapping the tapping cut is exposed to two days' drying in place of the regular one. In Method 2 the cut suffers more severe drying, for three days, twice a month, but between the rests there are six tappings at regular intervals. It might be expected then that these two systems would give different results.

The results of these experiments are not sufficiently uniform to settle this point, but differences between the two systems are suggested. (See Table 2). On two of the three estates employing Method 1, the percentage loss of crop was greater than the loss of tapping days. All five of the estates on sections using Method 2, gave a loss of crop smaller than the reduction in tapping days. Thus on the whole the loss of crop was greater when the Sunday rests fitted Method 1 than when they fitted Method 2.

## Individual Tree Yields.

As the numbers of tappings per month and the numbers of trees in a tapping task vary from one estate to another strict comparisons can only be reached by reducing the figures to individual tree yields.

Table 3 shows that the previous conclusions can be reached in another way—the mean yields per tree per tapping are mostly higher for the trees rested by Method 2 than for the control trees, while Method 1 gave yields slightly more on estate B, and rather less than those of the control trees on estates C and K.

Table 3. Mean Yield per Tree per Tapping—pounds.

| Estate. | | Control | System 1. | System 2. |
|---|---|---|---|---|
| B | 1st period | Block A. 0.1064 | Block B. 0.0920 | |
| | 2nd do. | Block B. 0.0823 | Block A. 0.0978 | |
| | Mean | 0.0943 | 0.0949 | |
| C | | 0.0470 | 0.0452 | |
| J | Section A. | 0.0258 | | 0.0274 |
| | Section C. | 0.0278 | | 0.0323 |
| K | 1st period | Plot 12. 0.0205 | Plot 13. 0.0205 | Plot 14. 0.0209 |
| | 2nd period | Plot 13. 0.0258 | Plot 12. 0.0246 | Plot 14. 0.0255 |
| M | | 0.0364 | | 0.0394 |
| S | | 0.0661 | | 0.0710 |

## Daily Yields.

In order to follow the effect of the extra rest days it is necessary to consider the yields for the different days in the week. Only estate C sent in yield figures for each tapping. Two tappers were employed on two blocks tapped alternately, but as the average yield for Block S is considerably higher than for Block O they are first treated separately. In this analysis only the yield of days fitting into the proper sequence are considered; if rain or holidays introduced an extra non-tapping day the yield of the next tapping is not included. The mean figures thus represent from 22 to 26 weeks for alternate day tapping, and 36 to 38 regular week days after the Sunday rest (Method 1 was followed) with 9 to 12 weeks when the regular sequence had been disturbed.

There is no reason why the mean yield over a year should be different for any one week day and it is found that for Block O the mean yields vary but little from day to day; the lowest is 2.67 pounds for Wednesdays and the highest for Thursdays is 2.84 pounds. The mean of all is 2.77 lbs. The standard errors of the lowest and highest means are $\pm$ 0.13 and $\pm$ 0.11 pounds respectively, and their difference (0.17 pounds) is not significant.

For the task rested on Sundays the regular tapping days were Monday, Wednesday and Friday, and their mean yields 2.65 ± 0.10, 2.65 ± 0.09 pounds respectively. For the twelve weeks when the tapping order had been varied the means for Tuesday, Thursday and Saturday were 2.81, 3.06 and 3.11 pounds.

Table 4. Mean Yield of Week Days (pounds).

| | Alternate Daily Tasks | | | | | Sunday Rested Tasks | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Block O | | Block S | | Total | Block O | | Block S | | Total |
| Sunday | 2.77 | **24** | 3.85 | **25** | 6.62 | | | | | |
| Monday | 2.72 | **26** | 3.90 | **25** | 6.62 | 2.65 | **38** | 3.78 | **11** | 6.43 |
| Tuesday | 2.81 | **24** | 3.67 | **24** | 6.48 | 2.81 | **12** | 3.34 | **37** | 6.15 |
| Wednesday | 2.67 | **22** | 3.73 | **26** | 6.40 | 2.63 | **38** | 4.06 | **10** | 6.69 |
| Thursday | 2.84 | **25** | 3.46 | **23** | 6.30 | 3.06 | **12** | 3.60 | **36** | 6.66 |
| Friday | 2.76 | **23** | 3.85 | **25** | 6.61 | 2.76 | **38** | 3.85 | **9** | 6.61 |
| Saturday | 2.81 | **25** | 3.52 | **24** | 6.33 | 3.11 | **12** | 3.61 | **37** | 6.72 |
| Mean | 2.77 | | 3.71 | | 6.48 | 2.83 | | 3.71 | | 6.54 |

The heavier figures are the numbers of weeks included in calculating the mean.

Thus, though the differences are not statistically significant both sets of figures show the same tendency for the mean yield to increase towards the end of the week.

In the same way on Block S the alternate daily yields varied from 3.46 ± 0.20 on Thursdays to 3.90 ± 0.18 on Mondays with a mean of 3.71 lbs. There is also an apparent tendency for yields to fall off through the week. The other tasks were tapped mostly on Tuesdays, Thursdays and Saturdays and gave mean yields of 3.34 ± 0.155, 3.60 ± 0.14, and 3.61 ± 0.17 lbs. In the other weeks the mean yields on Mondays, Wednesdays and Fridays were 3.78, 4.06 and 3.85 lbs. That is, as on Block O, the yields were lower just after the rest than later in the week.

Addition of the yields from both blocks eliminates any possible difference due to the two tappers, and shows clearly that yields on Mondays and Tuesdays are lower on the rested than on the control tasks, but from Wednesday till the end of the week are equal or greater. The mean yield per tapping of the control tasks

is slightly lower than that of the tasks rested on Sunday, and so the loss of crop should be slightly less than in proportion to the loss of tapping days. The reverse result obtained from the total crop figures has been influenced by the tapping days after rain days and holidays, which were not included in this analysis.

It is interesting to compare these figures with those received from four estates for previous periods without Sunday tapping.

Table 5. Yield of Week Days as Differences (per cent).

| Estate | Locality | Date of Experiment. | Duration month | Friday to Monday as % of Friday | Saturday to Tuesday as % of Saturday | Week's mean Monday as % of week | Week's mean Tuesday as % of week |
|---|---|---|---|---|---|---|---|
| C | Selangor | 1923 | 7 | 4.2 | 3.6 | | |
| | | 1930 | 12 | 2.7 | 8.5 | 1.7 | 6.0 |
| G | Perak | 1924 1925 | 6 | 2.1 | 2.4 | | |
| S | Selangor | 1929 | 12 | 4.5 | 8.5 | 1.4 | 5.5 |
| SR | Selangor | 1927 | 6 | | | 7.4 | 2.7 |
| | | Mean | | 3.4 | 5.7 | 3.5 | 4.7 |

There were no control fields or tasks on continuous alternate daily tapping, and the figures quoted are the mean yields over various periods for Mondays and Tuesdays compared with Fridays and Saturdays or the whole week. Only for estate S are figures given for all the six days after the rest day. All of these data confirm the conclusion that yields are low immediately after the rest but increase towards the end of the week.

### Dry Rubber Content.

Only two estates submitted details of the dry rubber content of the latex. On estate C the mean for both blocks for twelve months is 3.77 pounds per gallon for the alternate daily tasks and 3.74 for the Sunday rested tasks, but in nine out of the 24 pairs of figures the dry rubber content is higher for the rested than for the continuous tasks. On estate M in each of the 5 months the mean dry rubber content was greater for the rested than for the control tasks, and the means for the whole period were 4.08 and 3.97 pounds per gallon respectively.

Thus there is no evidence available to show that there is any appreciable difference between the dry rubber content of the latex from the tasks tapped continuously on alternate days and that from the tasks rested on Sundays.

## Summary.

1. Six estates have carried out experiments to determine the loss of crop from tasks not tapped on Sundays compared with tasks tapped continuously on alternate days.

2. The results vary somewhat, but on the whole the proportional loss of crop is slightly less than the reduction in the number of tapping days.

3. Two systems of resting were employed: one involving two days' rest every week, and the other three days' rest in alternate weeks.

4. There is a suggestion that the loss of crop is less from the second than from the first system, and this is related to a greater yield per tree per tapping.

5. Yields are low just after the rest, and increase towards the end of the week.

6. As far as can be judged from the available figures, the dry rubber content of the latex is not affected.

# THE FORESTRY SYSTEM OF RUBBER PLANTING.

## Introduction.

This article discusses the problem of rubber cultivation under so-called forestry methods of cultivation, with special reference to the experiments conducted by Mr. Birkemose on an estate in Pahang. The article has been compiled by the Head of the Soils Division, after a consultation with the Director and the Heads of the Botanical and Pathological Divisions, the appropriate section on diseases being contributed by the Head of the Pathology Division. It is hoped that the statement will meet the need expressed by many requests from managers and agency houses for information on the subject.

1. General Theory.
2. Statement of Birkemose System.
3. Description of Birkemose Results.
4. Comments and Criticisms.
5. Summary.

## General Theory.

Before proceeding to any detailed discussion it will be well to get a clear idea of the problem by means of a short statement of the general theory which is involved. The natural habitat of Hevea is the tropical rain forest, of which the natural cover of the Malay Peninsula is a typical example. The soils most suited for forest growth are deep and well drained, and carry a tall close stand of deeply rooted trees. Considered as a whole the forest is a stable and unchanging assemblage of most varied organisms, including plants and animals of all sizes down to the micro-organisms of the soil. The individual units of this assemblage are in a state of constant activity, so that the balance is like that of a top which remains steady while spinning with great speed and energy. The analogy is close, for on analysis the activities of a forest are found to repeat themselves in a revolving or cyclic fashion. Through their roots the plants draw water, and mineral and nitrogenous nutrients up from the soil and, combining these with carbon dioxide taken from the air, build up great quantities of living organic tissue. In the course of time this tissue dies and falls back to the surface of the ground. Here, in conditions of high shading and

high moisture, the various micro-organisms (fungi, bacteria) carry out the work of digestion and decay, releasing carbon dioxide again to the air and passing the mineral materials back to the soil. The most vital function associated with this activity is the fixation of nitrogen, the most important plant food, by certain species of soil bacteria. In consequence of this continuous cycle the soil has always a surface layer of open texture, aerated, active and possessing plant-food reserves, in spite of the fact that the soil is constantly depleted by the leaching of excessive rainfall. The nitrogenous food of the plants can only be elaborated if the micro-organisms can find organic material for their food and the other conditions of temperature and moisture favourable to them, so that nitrogen supply becomes the most pressing factor in the situation for crop growth when the forest cycle is broken. What might be called the rate of revolution of this forest cycle is high in such regions as Malaya, owing to the high temperature and the absence of the retarding effect of cold or dry seasons, and the appearance of great fertility is due to this rapid movement and not to any store of plant food supplies comparable with those associated with fertile soils in temperate climates. Speaking in terms of finance one might say that Nature is working, not on a large capital, but on a quick turnover.

A high rate of decomposition of detritus means that there is little visible accumulation on the soil surface, which remains relatively bare. It is important that this should be appreciated, for it is sometimes wrongly assumed that accumulations of dead but undecomposed material over the soil indicate greatly improved conditions, whereas it represents one half of the process without its necessary complement. The proper balance is only attained when activity of growth is accompanied also by activity of decay. In this connection it may also be noted that the type of shade and freedom at the soil surface produced by erect covers show points which make them preferable (other things being equal) to low growing creeping covers. The value of creeping legumes on new clearings may outweigh that consideration, as a rapid shading is the first advantage sought.

Such is the natural balanced state of affairs in the primeval forest and it is in strong contrast with the situation after clearing and prolonged cultivation and exposure of the soil have done their work. We then find the surface layer of the soil depleted of its organic matter and other available reserves, compact, hard and dead. Only under very favourable circumstances has the forest condition become restored under mature rubber with the methods of cultivation followed in the past. The temperature of the exposed soil is much higher than under forest, especially by day, and

it suffers violent drying out as a result of exposure in a way quite unknown in the original forest. In extreme cases nothing but the dead mineral skeleton of the soil remains. In varying degree most of the soils under mature rubber have suffered this deterioation. If left to Herself, Nature will again cloth the soil skeleton with the original life and fertility during the course of years. This process is carried out by the growth of a succession of floral species, accompanied no doubt by changes in the micro-organic population of the soil as well. By gradual steps of restored shade, humus, soil aeration and bacterial activity a state of affairs is built up which in most cases would be similar to the original, although without intelligent control the process is very prolonged. The first step is always the establishment of a few plant species only, which have special facilities for spreading or for utilising very poor and exposed situations. Most plants are not adapted to compete in these poor surroundings, so that a few species have it all their own way. Thus lalang, stag-moss and bracken have all the advantage of profuse wind-borne seed or spores. Other advantages which certain plants possess may be derived from association with nitrogen bacteria (legumes), or with mycorrhiza (possibly stag-moss), or from structural resistance to high insolation and drought. Though these plants appear in adverse situations it should not be too readily assumed that they produce or even perpetuate these conditions. Actually they perform the first steps of improvement in regard to moisture, shade, organic matter, and soil texture, and pave the way for the gradually diversified flora which follows.

Difference of feeding habit is a factor which contributes very much to the successful association of different plants together. It is normal, for instance, that forest trees feeding at great depths should be associated with other plants which feed at lesser depths and with ground covers of an entirely superficial feeding habit. Many of the latter are semi-saprophitic, that is, they feed on decaying matter directly rather than on the soil. They are therefore not competitors, though by too vigorous growth some of them may produce an unsatisfactory mat of surface roots. There can be no doubt that the rubber trees on many estates have developed a feeding habit much nearer the surface than would be natural to them under forest conditions. As already pointed out, nitrogen fixation is associated with the humus in the surface layers of soil, though it can be leached down to lower levels by water movements. When supplies of fixed nitrogen get scarce, and that is almost universally the case on estates, roots are encouraged to keep near the surface to be near the source of the meagre supply. This circumstance is undoubtedly one of the serious difficulties in the

way of rapid success being attained by the forestry method of rejuvenation, making it inevitable that the rubber should be at first abnormally sensitive to the effects of competition.

### Statement of Birkemose System.

The Birkemose system is based upon treating a stand of Hevea as a natural balanced forest. The plan has been tried before (e.g., in Java), but it seems fair that Mr. Birkemose's name should be associated with it at the present time, since his patience and initiative have been responsible for giving Malaya indubitable practical proof of the value of a new system of management. The following statement summarises the basic ideas upon which his experiments have been carried out.

1. "The principles of forestry are to control and regulate the amount of heat, light, wind, and (to some extent) the rain reaching the ground. These factors determine the success or failure of forestry." (Mr. Birkemose in "Straits Times" 19-2-32).

2. Regulation is achieved primarily through the natural ground covers, of which Hevea seedlings form the natural predominant feature in mature areas. In new clearings considerations of shade lead to closer planting than the conventional systems.

3. Careful selection is applied to the natural covers within the bounds set by the requirements of shade, etc. The system is therefore much more than a mere cessation of weeding; lalang control being of course taken for granted. Some plants are condemned on the type of root system, a close mat or tuft being considered harmful. Others are considered to maintain acid soil conditions by their root action (e.g., stag-moss). Plants with broad leaves and soft stems are encouraged. The formation of woody growth is not permitted, except in the seedling rubber which has a definite future as the dominant species and crop producer. The plants which appear are taken as an index of the stage of regeneration reached, the final improvement being indicated when the "nitrate feeders" appear—which are recognised by the greater softness and delicacy of tissue and the fresh green colour of the foliage.

4. The selective weeding is carried out by hand, no tools being applied to the soil, for fear of root injury and soil erosion. Plants are either pulled out or cut off near the ground. All material is left to rot naturally, this being accelerated by breaking up and pressing close to the soil surface, so helping to keep both moist. The use of lime (say 6 lbs. per tree) is considered to be of valuable assistance in hastening such decay and improving the seed-bed conditions for the new cover plants.

5. No pitting or bunding is considered necessary, complete reliance being placed upon the protection from erosion afforded by the plant cover. Contour paths or narrow terraces are made for accessibility.

6. In the main, root disease is viewed an as inevitable part of the forest complex, which will not get out of hand if natural stabilised conditions are maintained. Soil sanitation work is therefore omitted, except, perhaps, in preliminary stages in mature rubber. Reliance is placed upon a sufficient number of seedlings surviving owing to natural resistance even in old disease patches. Trees for removal are either ringed and left to decay or cut off close to the ground.

7. The maintenance of the stand indefinitely depends upon replacement of successive generations of trees growing together. Constant selection goes on guided by appearance and test tapping, the best trees being brought on by judicious thinning in their neighbourhood. The gradual replacement of an old stand with buddings by these means is considered feasible.

### Description of Birkemose Results.

As an illustration of the good results achieved one of Mr. Brikemose's experiments may be described in some detail. The area concerned is a hill-top, of which just over 8 acres were selected for experiment. The original planting was carried out in 1918 from secondary jungle of some eight years' growth. The planting distance was at 15 feet intervals along contour paths which were 30 feet apart. This rather open spacing no doubt had considerable bearing on the subsequent history. Tephrosia was first planted as a cover, but when this proved unsuccessful clean weeding was adopted and carried on for the next five years. The soil became hard and baked from exposure and wash and the trees began to show signs of stagnation. From 1923 onwards natural cover was allowed to grow, and by 1928 stag-moss and ferns had formed a complete carpet. During this time the trees went from bad to worse. Although only ten years from planting they stood with bare and dying branches. Tapping took place between 1924 and 1927 but had to be stopped owing to bad bark conditions. The area was then abandoned.

In November 1928 Mr. Birkemose took the regeneration of the area in hand. The stag-moss, ferns and bracken were pulled out and spread over the ground. Rubber seeds were then perseveringly sown at each seeding season. At first, although the seeds germinated, the seedlings mostly failed to establish themselves, but gradually success was achieved and early in 1930 a

full cover of seedlings was protecting the soil. Where dressings of lime were given the process of establishment was greatly assisted. Accompanying the establishment of this cover the soil texture gradually improved, and the trees started vigorous growth again. The area was inspected during 1931 and the original trees were found to be in an excellent condition of growth, the foliage being as heavy as if a nitrogenous fertiliser had been applied.

Tapping was begun again and, in spite of the low stand of trees, good yields have been obtained with every prospect of being maintained. The figures reported for the latter part of 1930 and the beginning of 1931 give rates corresponding to 600—800 lb., of dry rubber per acre per annum.

During the season at the end of 1931 the most vigorous seedlings were selected (average distance 6—8 feet) and budded. A slight clearing is made round each budded plant to give it enough light, and exceptionally vigorous growth is now (Feb. 1932) manifest in the new shoots. The intention is that finally the older stand will be replaced by this new budded stock. The forest conditions will remain through every step of the change, and the area, of course, remain in bearing.

A control plot of 3 acres forming part of this hill has been left under a heavy growth of stag-moss and bracken. The appearance of the trees in this plot remains poor, showing advanced and continuous dying back of the tops and a hard, white, brittle, and non-renewing bark.

In another area of rubber on steep land (285 acres) Mr. Birkemose has a good example of stabilised natural conditions. The trees are just coming to maturity so that here seedlings are entirely absent from the ground cover. There appears to be no sign of soil wash in spite of the fact that no earthworks have been undertaken, except small contour paths. The trees carry dense foliage right up to the crowns of the hills, producing enough shade to put a severe check on the cover. This forms a light carpet from which stag-moss, bracken, Melastoma and certain ferns and grasses are excluded by occasional hand weeding rounds. The soil is in an ideal soft, moist and cool condition.

A new clearing (109 acres planted in November/December 1930) is being raised by similar methods. Felling, burning and clearing up to 8 inches were done in the usual way, but no stumping, and then a dense natural cover allowed to grow. The rubber is planted at close intervals along contours. Selective weeding is in force in which any lalang, creepers and other undesirable growths are removed by hand pulling. This field is in excellent condition both with regard to the soil and growth of the young rubber. It is as yet too early to give an opinion of the ultimate result.

Since 1916 pests and disease patches have been regenerated by self-sown seedlings. Many groves of mature and healthy looking trees are in evidence all over the estate on such places.

We are indebted to the Forest Research Officer, F.M.S. (Dr. F. W. Foxworthy) for permission to reproduce the photographs of Plates I to IV, taken by him on Shanghai Pahang Estate early in 1932. They give a good idea of the various areas described above. It must be specially emphasised, in order to interpret these pictures properly, that the absence of any stereoscopic effect (and consequent apparent foreshortening) makes the undergrowth appear much more dense than is actually the case.

The whiteness seen on the tapping panels is a lime treatment used by Mr. Birkemose.

## Comments and Criticisms.

The first point which needs to be emphasized in discussing the foregoing description is that there is no reason to assume that equally swift success can be looked for in every endeavour to repeat Mr. Birkemose's rejuvenation scheme. Indeed, as one considers the important factors of age of trees, duration of the period of deterioration, and nature of the soil profile, it is seen that most of our poor mature areas will have a much more uphill fight. In many cases it is likely that some essential factor for success is entirely missing. But the single success establishes the soundness of some, if not all, of the underlying ideas, and it remains for reduplication of the experiment to discover how far the application can be made general.

The characteristics to be observed in this successful experiment are (1) the soil has a good deep profile (2) the trees were only ten years of age (3) the site had not been exhausted immediately before or after planting by cultivation of other crops. The chances of success are favourable in these circumstances, and remain good even in other cases where the age of the trees is greater. But the situation is very different for those areas which were planted originally on exhausted land. If the soil profile is deep the soil has always the possibility of restoration, but the recovery of old trees, starved since planting, will often be problematical. In these situations, too, the competition of a natural cover is so intense that the trees suffer, especially if no control is exercised. This is the main reason why natural covers have often been regarded as deleterious: the same cover in a less impoverished area will earn a better reputation. In many ways the problem offers the same difficulties as those discussed on former occasions in regard to manuring, for the main feature in the forestry reju-

venation is the restoration of activity to the natural process of nitrogen fixation in the soil, just as nitrogen supply has proved the main need in manuring. The same conclusion to which manuring results have led is therefore likely to hold for areas of prolonged stagnation in growth, namely, that if the soil seems capable of restoration it should only be undertaken in conjunction with a fresh stand of trees, i.e., replanting must be undertaken.

The next feature for emphasis is the amount of thought and supervision which the earlier stages of the process require. The plan is very far from offering a quick saving by the simple elimination of weeding and supervision costs. It can now be seen that the older plan of clean weeding, having the utmost simplicity for statement and practice, was a constant fight against a natural order. As such it ultimates in an unstable state of affairs, shown, for instance, in a sheet of lalang taking possession if the weeding is stopped. The new method envisages a natural balance attained by working with the natural tendencies rather than against them. The balance is somewhat removed from the completely free or wild state, it is true, but not so far that any serious disturbance takes place if there is temporary neglect. The return to these natural conditions needs careful watching and management. The situations which arise are very varied and require the same variation of detail in treatment. The old method was simple but has led to complications, the new one appears complicated at the start but should finally attain great simplicity. In the meantime it is to be realised that it definitely adds to the tasks of management to lay down areas for experiments with the method.

Considered from the point of view of soil management the system under discussion is eminently sound. The Rubber Research Institute has always advised on cultivation with the same ends in view. It is from the point of view of crop management (latex collection and care of trees) that adverse or modifying criticisms will come. Certain suppositions may have been made as a basis for selective weeding without the solid support of scientific proof, which can only be provided as a result of close research work, but this is not of first importance. The outline given in Section 2 can be taken as sufficient guidance for a practical start and knowledge will extend with practice accompanied by careful observations. It is certainly correct to say that the soil requires more shade and more organic matter than is given by the average stands of rubber. This should be attained at less expense by means of natural covers than by means of cultivated ones, with the added advantages that the position is a more stable one.

The limiting factor with reference to the adoption of a forestry method for rubber cultivation in Malaya is the question of root

disease. Forest conditions will provide an encouraging influence for the development of all the known stem and branch diseases and also for diseases of the tapping panel. These diseases, however, would not act as limiting factors to any degree; the requirements with reference to these diseases would be further research for control measures, if a forestry method was successfully established.

In connection with root disease the position is stated above as follows:—(a) In the main, root disease is viewed as an inevitable part of the forest complex, which will not get out of hand if natural stablised conditions are maintained. (b) Reliance is placed on a sufficient number of seedlings surviving owing to natural resistance, even in old disease patches. (c) Trees for removal are either ringed and left to decay or cut off close to the ground.

The term natural stablised conditions should not be misunderstood. Natural *stabilised* conditions will disappear with the cutting down of the forest species and replacing the natural flora with rubber trees. It is after the planting-up of rubber trees that an attempt should be made to obtain stabilised conditions chiefly by non-interference, so that many of the cultural operations practised in past years will be dispensed with.

The crux of the root disease situation lies in (c) above. The present disease position in old rubber areas is serious and the factor primarily concerned in the past was unscientific or careless thinning-out. The surplus trees were usually cut off at ground level, the tap roots and laterals being allowed to remain in the ground. In effect, the same results may be anticipated if forestry methods are adopted when the trees would be ringed and left to decay or cut off close to the ground, leaving tap roots and lateral roots *in situ*. Further, if no treatment is to be accorded to diseased trees, the whole effect would be cumulative, and serious trouble would be encountered in a much earlier stage of the plantations. It is difficult to conceive of natural disease resistance in connection with a disease such as "Wet-Root" rot of rubber trees, and the possibility may be ignored as an important factor in the problem. The success of the forestry method seems very problematical unless there is sufficient room left in the fabric of the scheme for the insertion of a systematic treatment of root disease. The basic forestry idea propounded in (a), (b) and (c) above, is diametrically opposed to the proposal of systematic root treatment and because of this, the disease position in rubber plantations raised under forest conditions would be as bad as, and probably considerably worse than, that in present day plantations, as far as our knowledge and experience of root disease allows a

judgment to be made. Finally, it may be stated that all recent discoveries made in connection with Wet-Root rot support the statements made above.

The forestry system as applied to existing areas of rubber divides into two distinct branches on the question of the treatment of the self-sown seedlings. On the one hand the full application of forestry treats these as the new generation which will be reared as required for the replacing of the old. While it is of the highest interest to experiment with such proposals, it will not be possible to advocate their extensive adoption until it has been proved for a longer period and shown to surmount the difficulties expected in regard to supervision of tapping and collection, and in regard to the systematic treatment of root disease. If, on the other hand, the seedlings are regarded as part of the natural cover to be controlled before they grow large enough to interfere with supervision or to be dangerous from a pathological standpoint, then we have rubber growing in association with the ground cover in a way that can be entirely commended. The maximum growth permitted to the seedlings under such supervision would be about three-quarters of an inch diameter of stem.

One small advantage of these covers which may be worthy of mention, is that the tread of the tappers is confined to paths. A special feature of many of our soils is the ease with which they compact and bind under pressure, and the ill-effect of the continual tread of the labour force is worthy of more attention than it has received.

In regard to dispensing with earthworks to stop erosion, it is obviously impossible to generalise from one successful case and accept the proposal for all soils and situations. At present it is regarded as a wise and justifiable precaution to make contour bunds on all sloping land. In conjunction with a successful ground cover such a system can be regarded as practically permanent, so that the first cost is the only expense.

## Summary.

It would be a great mistake at the present juncture to attempt to lay down rule-of-thumb regulations by means of which rejuvenation under this system could be attained. The different situations vary far too much for this. It is essential to understand the elementary principles of what is aimed at and to adapt procedure to the existing situation as presented by each field of rubber. Thus it is necessary for managers to select or reject plants on simple general grounds rather than to provide lists of botanical names,

which might apply well to one situation but afford no help in another. Guidance may be found in the following summary.

(1) Almost any cover must be welcomed at first to provide a beginning for shading and humus formation. No single species will, however, be left long enough to get out of hand. During this stage competition is likely to prevent the rubber from showing signs of improvement.

(2) If the species appearing are mainly undesirable then they may be suppressed by slashing or pulling. Better still they should be weeded out and left to decay with a dressing of lime, when a renewed and diversified flora should succeed. There is evidence to show that a rubber seedling cover can be used successfully to bring about these changes. Slashing may be useful at first but finally must be abandoned in favour of hand pulling, since it does not exercise the right selection.

(3) Plants should be selected on their shading properties, root habit and the rate of decay of their tissues when they die. Shrubs which tend to produce woody stems and roots (e.g., Melastoma (Singapore rhododendron) and rubber seedlings) should be cut down or pulled out before they become too large. Ferns and grasses whose roots form thick tufts or a close mat near the surface of the soil should be discouraged. Other ferns and grasses with light spreading root systems may be left. All creepers are kept down as they interfere with other plants. Stag-moss and bracken are suppressed. All large leaf plants and all those with soft easily-decomposed tissues are encouraged.

To consider that a quick-acting cure-all has been found in a system of forestry is to take an unduly optimistic view of the agricultural position of old stands of rubber. In any case an appeal to natural methods is bound to be slow and sure rather than sudden in the results obtained. This is one feature in which the methods of management greatly differ. Forestry changes go by little and little, which is in contrast with cultivation operations conducted right through at once with concentrated labour forces. Estates should be encouraged to experiment along the lines suggested, not forgetting to leave a small block as control to afford scientific comparisons. As experience develops for various situations the detail will be filled in. Management problems of training labour, of costs and supervision will all have to be examined by the test of experience before a final judgment can be reached. But with due regard to adaptations to meet the requirements of management and control of the root-disease situation, it may be said that the proposals have distinct possibilities of improving the results and cheapening the costs of rubber cultivation.

PLATE I.

New clearing, rubber one year old, 800 trees per acre.

PLATE II.

Hevea seedling cover in early stage.
Mature rubber planted 1910, seedlings two years old.

PLATE III.

Typical result of selective weeding under young mature rubber.
Planted 1926, 300 trees per acre not yet thinned out.

PLATE IV.

Typical mixed stand under forestry control, in relatively early stage.

# RUBBER ROADWAYS

## A Review

BY

J. D. Hastings.

As far back as 1870, at St. Pancras Station, London, a road leading to the arrival platforms was paved with rubber slabs. These were two inches thick and while some have been taken up, replaced or relaid, there are in use at the moment some of the original slabs still in good condition, a striking testimony to the life of rubber as a road making material. Little more seems to have been done until 1913, when the Southwark Council was approached for permission to lay a small experimental stretch of rubber paved road. This was allowed and a section of two or three square yards of rubber-capped wooden blocks was laid at the junction of the New and Old Kent roads. After a year and nine months, the blocks were taken up for examination; little surface wear had taken place but the anchorage of the cap to the block was unsatisfactory and there was wear between the under side of the cap and the top of the wood. In 1915, Rubber Roadways Ltd., a Company to foster the use of rubber for roadways, was formed under the auspices of the Rubber Growers' Association for collaboration with manufacturers and inventors to try out many of the ideas and patents that the earlier test had brought forth. Many of these were unsatisfactory, due to the difficulty of anchorage of the cap. In 1918, the Leyland and Birmingham Rubber Company Ltd., evolved the Leyland block and in the early part of 1920 a section of road in Southwark was laid with these blocks. These had a rubber cap attached to vulcanite which was fixed to a steel plate with projections on the under side, these being embedded in the wet concrete foundation of the road at the time of laying. Within a short time, some 15 per cent. of the blocks had shifted from the plates, and accordingly, half the area was taken up and replaced with blocks having a plate of expanded metal with projecting lugs embedded in the vulcanite: these were an improvement.

The anchorage of the cap continued to be the chief difficulty, the actual wear on the surface being negligible, and the position with regard to the use of rubber as a road surfacing material is expressed in the statement of the Chairman of Rubber Roadways Ltd., who said in 1922 " there is no question of the wearing and

other properties claimed—the problem is now one of attachment to foundation."

Further investigation by the Leyland and Birmingham Rubber Company Ltd., led to an alteration in the design of their block, and in 1923, the improved type was laid in another section of road in Southwark. The block now consisted of an upper portion, half an inch thick, of rubber similar to the old cap and a lower 2½ inches of very hard rubber, the two being vulcanised together. These proved very satisfactory and when removed in 1926 shewed little wear. That a great deal of investigation was being carried out is evident in the statement made in 1925 by Rubber Roadways Ltd., that over 70 patents for the use of rubber as road material, mainly in the form of blocks, had been granted within the previous few years.

Today the anchorage question has been completely overcome, and there can now be seen in England and Scotland, as well as on the Continent, a number of sections of roadways paved with one or more of the following five principal blocks:—

(1) The Leyland block previously mentioned, laid in 1924 on a stretch of roadway at Fresh Wharf, London Bridge.

(2) The North British block laid in Edinburgh and Glasgow in 1923. A feature of this block is the size of the concrete base which is smaller than the rubber cap and thus ensures improved grouting when the blocks are laid.

(3) The Cowper block in Thurloe Place; an interlocking, all rubber 3 layer block, grooved and recessed on the sides, giving a very good surface joint, laid in 1928 after earlier trails had proved very successful.

(4) The Gaisman block, a rubber cap vulcanised to a hard highly vitrified brick base, laid in 1926 in New Bridge Street, London.

(5) The Cresson block, a rubber cap fixed to a base containing stone, sand and other ingredients mixed with latex, all of which are pressed together and vulcanised when dry. Laid in Croydon at the end of 1928 following its successful use in Singapore since 1922 where blocks removed in 1927, apart from a slight surface cracking due to the tropical sun, were in excellent condition with practically no wear—incidentally the road adjoining had been repaired three times within that period.

All these trials now taking place are in areas where traffic is heavy. In addition to shewing no sign of wear, the reduction in noise and vibration is particularly noticeable. In 1922 a series of

sound records were taken near the Cenotaph, London, after rubber paving had been laid. The paving, although unsuccessful as far as the maintenance of the road was concerned, provided valuable data on the use of rubber as a vibration absorbing medium. The actual measurements shewed a 30 per cent., reduction in noise as compared with that transmitted by the adjoining wood paving and the remaining sound was less objectionable.

Late in 1927, more accurate measurements on vibratory conditions in buildings adjoining the rubber road in New Bridge Street were made on behalf of Rubber Roadways Ltd., and proved conclusively that vibration was much decreased with less damage to foundations of the buildings in consequence.

The present situation with regard to rubber blocks is that while every test indicates that wear is reduced to a very small amount and vibration is largely absorbed, the initial cost of laying the road is too high for large scale work. Considerable reduction in cost has been effected; when trials were first started the cost per square yard was approximately £5; at the Annual Meeting of Rubber Roadways Ltd., 1930, the Secretary was able to state that Firms were prepared to produce at £2.10.0 per square yard. This compares favourably with granite setts at £2.0.0. Moreover, in 1929 two areas were laid, on which the manufacturers gave a free maintenance guarantee for 5 years.

As alternative to the use of rubber-capped blocks there are the possibilities of slabs of rubber laid on similar lines to the early experiment at St. Pancras Station. Quite recently a trial has been started in Paris in the Quai de la Râpée using long slabs of rubber, laid on a cement foundation with hot melted asphalt between the rubber and the concrete as the binding material. The slabs were 8 to 9 metres long and 0.80 metre wide, made in two layers, the top being much thinner than the bottom which is in direct contact with the foundation. So far, no reports are available; there is a section of Gaisman block quite near, laid in 1929, so that a comparison will be of great interest. About one year ago, in the Ipoh district, trials with rubber carpeting embodying very similar ideas were made by two local inventors. Reference to a trial of this product by the Institute is made later.

The possibilities of using rubber incorporated with ordinary road materials have received attention from a number of investigators, and many patents have been taken out for preparations. As long ago as 1904, rubber had been incorporated with asphalt and laid at the Place de la Gare, Cannes, where traffic was said to be especially heavy. This is still in existence, while large stretches of rubberised asphalt are to be seen at Monaco and Cannes laid in 1912 and still in good condition. Little information is available

relating to costs, and it seems difficult to see how the quantity of rubber introduced—which is from 2 to 5 per cent—could effect the improvements in quality of the road surface to the large extent claimed.

In 1922, a trial was made in England and Ceylon by boiling down low grade rubbers in open pans yielding a tarry residue which was applied to the road. The result was not satisfactory, and at the same time the process lost the distillation products of the rubber which were not collected.

Much work has been done on the destructive distillation of raw rubber, and the oil obtained has many possible applications. Rubber oil, in common with bituminous oils, has a solvent action on rubber itself, and its utility as a solvent for rubber and asphalt or bitumen has been investigated. In spite of the mass of patents granted and literature written on the incorporation of raw or vulcanised rubber into ordinary road materials, it is not evident from the practical results that a cheap and satisfactory compound has yet been produced by these means. In fact a recent text book on roads dealing very fully with all classes of roadmaking materials does not even mention rubber asphalt compositions.

As another alternative to the block there is the possibility of starting with rubber in the form of latex and from this evolving a material that can be laid by spreading.

### Investigations at the Rubber Research Institute.

As a result of discussions late in 1930 between the Chief Secretary to Government, Federated Malay States, the President of the Board and the Director of the Rubber Research Institute it was agreed that investigations on the possible application of latex products to roadways were desirable and that such investigations could be best carried out in this country where supplies of latex are available.

It was also agreed that it was essential in the first instance to carry out chemical investigations in the laboratory and that the co-operation of roadway engineers was only possible at a later date.

The Board of the Institute accepted the recommendations put forward and agreed to allocate funds from its income towards the cost of the investigations and to appoint a chemist to undertake the work.

It was decided that the work should be controlled by a Committee of the Board of the Institute entitled the Rubber Roadways Committee, consisting of the President and two other members of the Board together with the Director and an officer

of the Public Works Department, Federated Malay States, appointed by the Director of Public Works, F.M.S.

The Committee applied for and obtained a contribution from the Rubber Experimental, Research and Propaganda Fund Advisory Board for the financing of practical road trials with any promising product which might be evolved.

The Director of Public Works, Federated Malay States, also promised the co-operation and advice of his staff in connection with such trials.

Work was commenced in March 1931 in the Chemical Division of the Institute, Dr. E. Rhodes being the Executive officer, and has been continued since May 1931 by Mr. J. D. Hastings who was appointed as special chemist to continue the work under the supervision of Dr. Rhodes. Dr. Rhodes proceeded on leave in May till the end of the year and made a number of valuable enquiries and contacts in relation to the problem while on leave.

The work done and the problems encountered are best dealt with under the following headings:—

Compositions made from latex.
The Laboratory testing of the compositions.
Rubber Roadway Compositions of Public Interest.

### Rubber Compositions made from Latex.

A rubber road material made from latex laid on the road as a paste necessitates the incorporation of other bodies as fillers. Rubber blocks like motor tyres are not made of pure rubber. Non-rubber constituents are added to give hardness, resistance to abrasion, long life to, and mask some of the characteristics of pure rubber that would be undesirable; moreover the larger proportion of these constituents must be cheap.

The choice of a filler when using latex as the rubber base will depend on the state of division in which the filler is obtainable, or to which it can easily be reduced. The state of division or particle size affects the ultimate strength of the filled rubber very considerably; in general the finer the filler the stronger the resulting product. Carbon black which is used extensively in the motor tyre industry is obtainable in an extremely fine form and to this largely owes its value. The use of mineral bodies as fillers for latex as a road material are therefore limited to those which can be obtained in a very fine form such as the clays.

A great deal of time has been spent on the problem of incorporating mineral bodies and compounding latex with various types of filler. We have made a large number of mixtures in the laboratory embracing the use of all the possible materials available.

Each class of filler has been found to have its peculiarities and effect on the ultimate product, to confer in some cases desirable, and in other cases undesirable, properties. For example the incorporation of carbon black while being of great value is only achieved with difficulty, and its use in large quantities renders control of the mix uncertain and difficult.

Many of the mixes prepared in the laboratory have shown possibilities; at the same time it was thought that they would not behave in the same way when used in practice. In order to obtain information on this point a small section of road foundation was laid at the Institute, similar to that used in ordinary road construction.

In using latex as the source of rubber, there is the difficulty of working with a relatively unstable liquid as compared with the stable and solid condition of ordinary rubber. Before the incorporation of any kind of filler can be attempted the latex must be stabilised. Many classes of substances useful for this purpose are known, in general protective colloids such as the soaps, casein, gums and others. These have been used during the work, which has shown that the uniform incorporation of fillers is not easy; moreover as the mix becomes more paste-like the difficulties increase. Liability to coagulation becomes greater which means that larger quantities of stabiliser are necessary; this is a disadvantage in the final product when applied to the road owing to retarded coagulation and increase in "setting" time.

Our experiments have shown that a material made from latex and applied to the road as a paste must have the contained rubber in an uncoagulated condition. This is essential for natural anchorage. Once coagulation has taken place these materials have lost their paste characteristics and cannot be laid on the road with the expectation of a firm anchorage; neither can one piece of material be joined to another by pressure alone.

The work on the anchorage problem indicates that if applied as a paste, when "setting up" (coagulation of the contained latex) does occur, a firm hold is obtained on the surface of the road, and from this point of view a foundation that is not graded up to the fine surface known as "blinded" is preferable. It was at first thought that consolidation subsequent to laying, which causes a thinning out of the material might destroy the anchorage established by the "setting up." This does not appear to be so.

Our work with field latex very soon showed that the principal problem was the removal of the water content from the mix. The water can only be lost in two ways, viz., by drainage or surface evaporation. The latter is very much faster and it does not appear possible, assuming a mix to give an excellent material when freed

from water, to get it on the road in such a state with any degree of thickness. The drying out subsequent to laying causes cracking. Thinner surface films are possible.

Attempts to limit the initial water content have been tried, such as concentration of the thinner mixes by creaming, the use of concentrated latex, and the preparation of extremely thick pastes by the use of large quantities of filler. Concentration of thin mixes by creaming was unsuccessful. The cream was unstable and separation of fillers took place. It has not yet been possible to investigate the question of concentrating compounded latex by evaporation, plant of a special type is needed similar to that used in the manufacture of Revertex. The experiments tried have so far indicated the inadequacy of ordinary laboratory methods.

The use of concentrated latex has been investigated. Results show there is more possibility of avoiding the cracking experienced with field latex, the use of which has been practically abandoned on this account. The form of concentrate mostly used at the present time is that obtained by creaming methods. Research on creaming is being undertaken in the Chemical Division of the Institute and a supply of concentrates of different types is readily available.

The difficulties of compounding concentrated latex are greater than with field latex; the uniform introduction of large quantities of filler is more difficult. Unless a large amount of stabiliser is used very thick pastes cannot be compounded; the presence of excessive amounts of stabilisers is however undesirable as such bodies tend to delay coagulation when the mix is laid and retard hardening. The disadvantages of heavily compounding concentrated latex are recognised in those manufacturing processes using very thick compounded mixes and it is more general to concentrate compounded latex.

It has already been mentioned that the uniform introduction of filler into a thick paste is not easy; the thicker the paste the more difficult does it become to achieve uniformity. From the experience gained in the laboratory, working on a small scale by hand under very definitely controlled conditions, it was thought that mechanical mixing, or mixing that could be applied to roadside practice would present considerable difficulty. By the courtesy of a local company it was possible to use an internal mechanical mixer of a well known type. The results were not satisfactory, difficulty was experienced in getting a uniform paste of the same even consistency as that obtained by hand in the laboratory.

Our earlier work on the use of fibrous bodies and cements as fillers has led us to continue on these lines; while an enormous

amount of work remains to be done, it appears that the use of certain types of these fillers may be of great value. Mixtures have been made which are less liable to crack on drying, while the use of cement to remove the water by chemical means has shown promise.

A paste mill has been installed at the Institute and has been of great help in connection with work on fibres. So far it has not been possible to use it successfully with the work on cement, because of the difficulty of controlling coagulation.

The early difficulties of uniformly incorporating, to any desired degree, chemically dehydrating fillers such as cement and Plaster of Paris, have been overcome. The time spent on this problem has been justified and from the small scale laboratory experiments it has been possible to make mixes on a large scale with the same measure of success; at the same time the methods employed are applicable to the incorporation of other types of filler.

A good deal of work has been done on the incorporation of bitumen and asphalt into latex with a view to preparing a paste material. It is not possible to introduce bitumen direct. Its incorporation as an aqueous emulsion is simple, but the implied fact of any added water is a disadvantage. The problems connected with the compounding of a latex bitumen mix are similar to those already described for ordinary latex pastes. Investigations on the use of bitumen emulsion in combination with latex as a surface dressing have been carried out at the Institute but there is no proof yet that such preparations are an improvement on the ordinary bitumen emulsions now in use, from an ageing and wear point of view. Further, such a combination applied as a thin dressing will be of no value in relation to absorption of vibration.

Preliminary work on the use of vulcanised latex has been studied. Attempts have been made to follow the changes due to the use of certain ultra accelerators with variation in time of standing for different quantities of accelerator; using an uncompounded latex with a view to ascertaining whether its behaviour when used in a compounded mix is comparable to that when used in latex alone.

### Laboratory Testing of Rubber Compositions made from Latex.

Work on the compounding of latex and incorporation of the various fillers has led to the need for a testing technique. This is an entirely new field of work, for at present there is no technique, and nothing is known about testing latex base materials for rubber roadways.

In common with all articles containing rubber the life and wearing properties of a rubber roadway mix will almost certainly depend on the state of vulcanisation of the contained rubber. It is necessary to be able to follow any changes in the rubber that occur with time, more especially in the early stages of its life. The ordinary testing methods, such as permanent set or stress-strain relationships cannot be applied to latex mixes of the type suitable for road application. The determination of free and combined sulphur content and hence vulcanisation coefficient by the usual methods of sulphur determination commonly applied to rubber have been found unsatisfactory when applied to road mixes and inadequate as a measure of the degree of vulcanisation.

Investigations on the rate of change of swelling in organic solvents with time have been carried out, although it has not been possible to correlate the amount of swelling with degree of vulcanisation, small changes in this are detected. In conjuction with swelling tests, stress-strain relationships have been studied where possible and qualitative conclusions regarding the state of vulcanisation have been deduced in agreement with tensile measurements. With a road mix containing bitumen or other constituents soluble in organic solvents this test is not applicable and so far there does not appear to be a line of approach for such materials. Variation in degree of vulcanisation at different depths added to large differences due to small changes in size and shape of the pieces under test make the evolution of a standard test difficult and unlikely.

With regard to abrasion testing several types of instrument have been tried, all of which have not proved completely satisfactory. A machine capable of dealing with very small samples giving a complete surface abrasion in a manner akin to the type of abrasion to which the material will be subjected is necessary. At present there is no machine suitable for these needs available here. Our experience has however indicated on what line work should be continued.

The artificial ageing of compounds can now be investigated. A Bierer Davis Oxygen bomb has been installed and its use on roadway mixes followed by chemical examination may enable us to predict how materials will age under normal conditions.

Development in testing technique are more likely to be directed towards the evaluation of physical rather than purely chemical tests. Should a material be satisfactory under such tests as abrasion, swelling, tensile strength, permanent set, hardness or plasticity followed by chemical examination before and after ageing we are certainly better fitted to predict its behaviour under

actual road conditions than to apply only the test of service which at present is apparently the only criterion.

In a wet mix the evalution of a test for shrinkage and its rate at different temperatures also becomes of great importance.

### Rubber Roadway Compositions of Public Interest.

The laying of experimental areas in Singapore of a proprietary roadway composition have been watched. Visits have been made, the actual laying of the paste observed and its subsequent behaviour on drying. The paste used was of the same general type as those with which we had been experimenting for some time. The problem of incorporation of suitable fillers does not admit of much variation. The drying of the paste was only obtained at the expense of contraction and resultant cracking. For any material to be successful the possibility of water penetration must not exist.

A bitumen emulsion from England has been investigated in connection with its use with latex. Laboratory tests have shown it to be very similar in behaviour to Colas, an aqueous bitumen emulsion made by the Asiatic Petroleum Company. On standing, separation of the bitumen from the latex rapidly takes place. Test strips were laid at Petaling with a bitumen and latex mixture in the proportions recommended. These were unsatisfactory and a further trial, using different methods of application, was laid. It is yet too early to pronounce definitely but indications of wear show that the mixing of latex with bitumen already emulsified yields too thin a product, at the same time an elastic surface skin is formed which is more easily peeled off, the plastic nature of the bitumen being masked. Trials have recently been made by the Asiatic Petroleum Company with preparations of latex and bitumen. The preparations used by them differ from simple mechanical mixtures of latex and bitumen emulsion in that the bitumen is emulsified not in water but in latex itself; the product therefore contains less water than is present in a mechanical mixture of two aqueous media.

The preparations have been patented by the above company and contain approximately 10 per cent., of rubber. Trials have been made at Colombo and also in Java, but the results are still inconclusive.

Following a favourable report on the "Silent Roadway" experiment carried out at Lahat by Messrs. Kendall and Graham in which thick rubber matting in strips was used, a similar trial under the supervision of the Rubber Research Institute has been laid with the co operation of the Public Works Department at Petaling New

Bridge, about 6 miles from Kuala Lumpur. It appears that the problems of anchorage and the prevention of water entering the foundations are likely to prove of far greater importance than wear and life of the rubber composition itself. A traffic census taken soon after laying gave the average weight passing over the area during the day as just under a thousand tons. This experiment is too recent to enable any definite conclusion to be recorded.

In addition to the trials recorded above, several samples of material for road making have been sent to the Institute for examination and report. The tests which have been carried out here have shown them to be unsuitable.

## Conclusion.

It will be seen from the foregoing that of the various methods which have been envisaged for the application of rubber to road making, only in the case of block paving has a satisfactory material so far been evolved. The difficulties of laying have been overcome and the chief obstacle to the wider application of the rubber paving block seems to be a reluctance to face the capital expenditure involved.

Attention has recently been focussed upon the possibilities of wet mixes prepared from latex,the underlying idea being that it should be cheaper to lay a material which can be poured or spread. This line of work has been actively investigated at the Institute and experiments are still proceeding. Sufficient experience has been gained to indicate that such a method though simple in conception is extremely difficult to perfect in practice. The difficulties encountered are numerous and it may be stated that, of a very large number of different preparations which have been made at the Institute, no single one can yet be judged as satisfactory from all points of view, although some have definite promise.

The experiments which have been made by outside authorities with proprietary materials of this type have all had some disappointing features. There can be no doubt that the really satisfactory wet preparation has yet to be evolved.

The prospects of success seem at present to be uncertain and if ever it is achieved it will be only as a result of the most patient enquiry.

# BALING OF RAW RUBBER.

BY

B. J. Eaton.

In view of the necessity for reduction of costs in the production and marketing of raw rubber, it appears desirable again to draw attention to the question of packing of raw rubber in relation to baling instead of packing in wooden chests.

Although the necessity is more urgent at the present time than previously, attention may be drawn to an article entitled" The Utilisation and Waste of Wood in the Preparation and Packing of Raw Rubber" published by the writer in The Malayan Agricultural Journal Vol. XII, Nos 6 and 7, June-July 1924 pp. 165-184.

In that article the possibilities of using a treated hessian or matting bale was discussed and figures of costs for packing in various wooden chests—Threeply, Momi etc., and Gunny sacking (hessian) were given.

As is probably well known, a few large manufacturers owning rubber estates and also several large manufacturers purchasing rubber in Singapore bale their rubber in treated hessian.

A letter has been addressed to the London Advisory Committee of this Institute suggesting that a questionnaire be sent to all the leading rubber manufacturers in Great Britain, United States of America and Europe to obtain opinions on the subject. Sufficient time, however, has not yet elapsed for the receipt of replies to this questionnaire.

At my request, Mr. A. Moore, Field Officer, Johore instituted enquiries among producers and manufacturing companies which were purchasing rubber in Singapore and shipping it in treated hessian bales. I am indebted to him for the details contained in this article which should be of interest to producers. Thanks are also due to the producing company using this method of packing for permission to publish the figures of costs.

## Use of Hessian for Baling Rubber.

On one estate treated hessian is used for baling all rubber except scrap which is packed in ordinary rice (gunny) sacks.

Hessian (jute) sacking is purchased at a cost of $104.10 per 1,000 yards 45 inches wide. The material is treated on the estate

with a size composed of tapioca starch and sodium silicate prepared as follows:—

| | | |
|---|---|---|
| Tapioca flour | ... | 120 lbs. |
| Sodium silicate | ... | 7½ „ |
| Water | ... | 120 gallons. |

The above quantity is stated to be sufficient for the treatment of 850 yards of hessian.

The mixture is contained in a shallow wooden tank fitted inside with rollers which are under the surface of the paste. The hessian is passed under the rollers through the paste and the excess of paste is removed from the hessian by means of two boards fixed near the edge of the tank. The hessian is handled rapidly by winding it on a revolving frame which pulls it through the paste. It is later unwound and hung out to dry before being used.

It has been found that, in a working day, five labourers can prepare 850 yards at the following cost:—

| | | | |
|---|---|---|---|
| 850 yards of hessian | ... | | $88.83 |
| 120 lbs. of tapioca starch | ... | $4.00 | |
| 7½ lbs. of sodium silicate | ... | 0.56 | 4.56 |
| 5 labourers at 40 cents each | ... | | 2.00 |
| | | Total | 95.39 |

3½ yards of hessian is sufficient for two bales of rubber, so that 850 yards is sufficient for 486 bales.

| | | | Cts. |
|---|---|---|---|
| Cost of hessian per bale | ... | ... | 19.6 |
| Cost of labour for packing and sewing per bale, | ... | ... | 11.0 |
| Cost of string and French chalk | ... | ... | 2.3 |
| | | Total cost per bale, | 32.9 |

250 lbs. of rubber can be packed in each bale, so that the total cost of packing (including labour) is 0.131 cents per lb.

The present cost of imported three-ply chests is not less than 85 cents, which at 250 lbs. per chest is equivalent to 0.34 cents per lb. of rubber, apart from the labour costs in making up the cases from the imported sides, bottoms etc., pressing, filling and nailing of cases, which bring the total cost to 0.4—0.5 cents per lb.

### Baling in "Grass" Mats.

The use of "grass" mats or mats made locally from "Meng-kuang" palm fibre has also been considered. Such material is used

for the baling of tobacco leaf and other products. Some years ago a patent was obtained in Malaya for mats of this type.

The following information has been obtained by Mr. Moore in connection with the cost of such packing, using "grass" matting imported from Hong Kong and Banjermassin. The rubber is pressed and strapped with tapes $\frac{3}{8}$ inch wide fastened by clips. The bale of rubber is then placed in the matting which is sewn up.

The costs are as follow:—

| | | | | | |
|---|---|---|---|---|---|
| Mats | ... | 18 | cents | per | bale. |
| Steel tapes (4) | ... | 10 | „ | „ | „ |
| Clips for fastening tapes (4) | | 2 | „ | „ | „ |
| Talcum powder and string | | 1 | „ | „ | „ |
| Labour | ... | 10 | „ | „ | „ |
| Total | ... | 41 | „ | „ | „ |

The above costs are for packing 250 lbs. of crepe rubber in bales. Costs for packing sheet would be considerably less, and it would probably be necessary to strap the rubber with steel tapes. If strapping can be dispensed with, the cost would be only 29 cents per bale or less than baling in hessian. Even if two tapes were used the cost would be only 35 cents per bale.

These mats also withstand very well the use of hooks used for handling. A point in favour of such matting is that it could probably be made locally as a village industry from locally grown material.

The following criticisms have been raised in relation to bale packing of rubber and are discussed under each heading.

(i) *Manufacturers prefer bale packing when shipping to their own factories and when the rubber is used more or less immediately after arrival.*

There does not appear to be any valid reason why rubber packed in bales should not be stored satisfactorily, especially in view of the fact that a layer of rubber is now invariably used as a wrapping round the contents of the cases or bales.

(ii) *In the case of estates having contracts with manufacturers, the price might be cut if the rubber were baled.*

This might happen and it is agreed that baling could only be adopted by consent in such instances or by all producers combining to effect this procedure.

(iii) *It is suggested that "massing" will occur in the holds of ships or in the warehouses in which the bales are*

*stored and that the warehouses would ask for higher rent for baled rubber, since the bales could not be stacked as high and would occupy more floor space.*

In view of the fact that all rubber is now pressed before packing so that the cases contain 224 or 250 lbs., of rubber per case (=10 or 9 cases per ton), no additional "massing" would occur during storage. If the bales are packed 20 feet high, the pressure on the lowest bales due to the weight of those above is only about 6 lbs., per square inch, which is less than that used when pressing the rubber into cases on the estate.

(iv) *Bale packing would appear definitely to rule out dealers, who are a big factor in the trade, since an estate confining itself to a manufacturer might find difficulty in disposing of baled rubber if manufacturers were not buying.*

This is agreed and it will be necessary to obtain agreement between manufacturers, dealers and producers in order to effect any change in the present procedure.

(v) *An objection might be raised in the case of rubber consigned say to London, and re-packed for the continent or elsewhere.*

It should be quite simple to re-pack the rubber in the same baling material or to place another wrapping of ordinary sacking outside the treated hessian. This would be cheaper than re-packing in wooden cases.

## Conclusion.

It has been shown that the packing of raw rubber in wooden cases is an unnecessary expense and that cheaper baling materials, in the form of hessian treated with a starch—sodium silicate paste, or "grass" matting, are quite suitable.

Emphasis might also be laid on the fact that the wooden cases at present in use are not a British or Imperial product, but are imported from foreign sources, while hessian is a British Indian Product prepared from jute grown in India and the starch-sodium silicate paste is also a British Product.

In the case of "grass" matting a useful local industry could probably be developed from locally grown material.

Two other points of interest and importance may also be mentioned. It may be found practicable and economical to treat hessian with a vulcanised latex. A cheap method which could be

adopted on estates would be to treat the hessian with a latex to which lime and sulphur (polysulphide of lime) are added. Such latex when dried is vulcanised and the baling material would be more waterproof. Both lime and sulphur are comparatively cheap and easily obtainable.

This method of treating the baling material would also result in a useful consumption of rubber in the form of latex. Experiments are required in order to compare the cost with the treatment described above.

Another important point is the size and shape of the bales in relation to shipping requirements and the width and length of sheet rubber in relation to factory machinery and coagulating tanks. It is possible that a bale of different size and shape to the wooden chests now in use may be more suitable.

# NOTICE.

## ESTATE VISITS.

The recent retrenchment proposals have resulted in a considerable depletion of staff and it is regretted that visits to estates will have to be curtailed. In order to help the staff of the Rubber Research Institute to maintain its high standard of advisory work as far as is possible under present circumstances, estate managers are kindly requested not to ask for visits to their estates unless advice is required on the spot upon matters of considerable importance. It is highly desirable that the experimental work of the depleted staff should not be interrupted more than is absolutely necessary and this end can only be gained by reducing the number of visits made to estates.

# ERRATA

Journal of the R.R.I., Vol. 1, July 1932.

(1) p. 37, line 22.

*for* "Lime-sulphur is an unsuitable substance"

*read* "Lime-sulphur is an unstable substance"

This is an important correction.

(2) p. 30, line 29.

*for* "systems" *read* "symptoms."